Airplane view of ponds at Sutton, Mass., of which an approximate contour map is shown on the cover of this report. These ponds were constructed by the State Department of Conservation, in part for the production of young fish for planting in other waters of the State. The value of the yield has been as high as $32,000 in 1 year.

MASSACHUSETTS DEPARTMENT OF CONSERVATION

74th Congress, 2d Session - - - - - - - - - - - Senate Document No. 198

Little Waters

A study of headwater streams & other little waters, their use and relations to the land

By H. S. PERSON
FORMERLY
Acting Director, WATER RESOURCES SECTION
Acting Chairman, WATER PLANNING COMMITTEE
NATIONAL RESOURCES COMMITTEE
Member, MISSISSIPPI VALLEY COMMITTEE
PUBLIC WORKS ADMINISTRATION

With the Cooperation of

E. JOHNSTON COIL AND ROBERT T. BEALL
RURAL ELECTRIFICATION ADMINISTRATION

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1936

SENATE RESOLUTION NO. 284

SUBMITTED BY MR. GUFFEY

IN THE SENATE OF THE UNITED STATES,

February 24 (calendar day, April 21), 1936.

RESOLVED, That the publication entitled "Little Waters, a study of headwater streams and other little waters, their use and relations to the land", be printed as a Senate document, and that 6,500 additional copies be printed for the use of the Senate Document Room.

Attest: EDWIN A. HALSEY,
Secretary.

PRESIDENT'S MESSAGE

To the Congress of the United States:

I transmit herewith for the information of the Congress a letter from the Chairman of the National Resources Committee with the accompanying report entitled: "Little Waters: a Study of Headwater Streams and Other Little Waters: Their Use and Relations to the Land."

This report treats of a subject with which the physical well-being of our people is intimately bound up, yet to which, in the past, too little attention has been paid. We have grown accustomed to dealing with great rivers, with their large problems of navigation, of power, and of flood control, and we have been tempted to forget the little rivers from which they come. The report points out that we can have no effective national policy in those matters, nor in the closely related matter of proper land uses, until we trace this running water back to its ultimate sources and find means of controlling it and of using it.

Our disastrous floods, our sometimes almost equally disastrous periods of low water, and our major problems of erosion, to which attention has been called by the reports of the National Resources Board, the Mississippi Valley Committee, the Soil Erosion Service, and other agencies, do not come full-grown into being. They originate in a small way in a multitude of farms, ranches, and pastures.

It is not suggested that we neglect our main streams and give our whole attention to these little waters but we must have, literally, a plan which will envisage the problem as it is presented in every farm, every pasture, every wood lot, every acre of the public domain.

The Congress could not formulate, nor could the Executive carry out the details of such a plan, even though such a procedure were desirable and possible under our form of government. We can, however, lay down certain simple principles and devise means by which the Federal Government can cooperate in the common interest with the States and with such interstate agencies as may be established. It is for the Congress to decide upon the proper means. Our objective must be so to manage the physical use of the land that we will not only maintain soil fertility but will hand on to the next generation a country with better productive power and a greater permanency of land use than the one we inherited from the previous generation. The opportunity is as vast as is the danger. I hope and believe that the Congress will take advantage of it, and in such a way as to command the enthusiastic support of the States and of the whole public.

FRANKLIN D. ROOSEVELT

THE WHITE HOUSE,
January 30, 1936.

LETTER OF TRANSMITTAL

NATIONAL RESOURCES COMMITTEE

INTERIOR BUILDING

WASHINGTON

December 19, 1935.

The PRESIDENT,
The White House,
WASHINGTON, D. C.

MY DEAR MR. PRESIDENT:

I have the honor to transmit herewith a report entitled "Little Waters: A Study of Headwater Streams and Other Little Waters: Their Use and Relations to the Land."

This report is noteworthy in that it deals comprehensively with a subject of high importance which has heretofore been neglected. Governments, private enterprises, and engineers have been concerned primarily with great waters and with the resulting problems of controlling major floods, developing hydroelectric power, providing for navigation, and irrigating arid lands. Yet it is the little waters which form the great waters. We must utilize and control small streams if we are fully to utilize and control great ones.

For the first time this problem is here inclusively treated. Scientific data made available by various Federal, State, and private agencies have been integrated from the point of view of the long-term public welfare, and the findings and recommendations are here formulated in a simple, clear, and convincing statement.

A reading of the text suggests the desirability of a comprehensive program of conservation which will enable us to make beneficial use of waters now permitted to go to waste, to save our lands from the disastrous effects of improperly-controlled run-off, and to remedy conditions that have proven socially and economically disastrous in numerous rural communities.

It is hoped that such a program may be undertaken without undue delay, and that further studies may be made in the same field. The effective control of little waters would, it is believed, be a lasting contribution to the Nation's prosperity.

Very sincerely,

HAROLD L. ICKES,
Chairman.

LETTER OF TRANSMITTAL

RURAL ELECTRIFICATION ADMINISTRATION

OFFICE OF THE ADMINISTRATOR

WASHINGTON

December 10, 1935.

Honorable HAROLD L. ICKES,
Chairman, National Resources Committee,
Washington, D. C.

MY DEAR MR. CHAIRMAN:

For administrative purposes there was initiated some 3 months ago by Soil Conservation Service, Resettlement Administration and Rural Electrification Administration, a joint study of headwater streams and related little waters. This was made a joint study because of the common interest of the cooperating agencies in the subject, little waters having a significance to erosion control, rural rehabilitation, and rural electrification.

The resultant study surpasses our expectations and has a greater value than that pertaining to the administrative purposes which stimulated it. It should have a place, we believe, in the series of reports on the development and use of natural resources. It brings together in a unique manner and from a new point of view, data accumulated by various public and private agencies. Its findings and generalizations have a social significance. It is comprehensive and authoritative, and has had the benefit of careful reading and constructive suggestions by eminent hydrologists, engineers and authorities on erosion, agricultural engineering and forestry.

For these reasons we believe that this report should be brought to the attention of the President, and by you as Chairman of the National Resources Committee in order that it may be identified with the series of reports on natural resources heretofore made. We take pleasure in handing you herewith copies of the report.

Yours very sincerely,

R. G. TUGWELL, *Administrator,*
Resettlement Administration.

H. H. BENNETT, *Chief,*
Soil Conservation Service.

MORRIS L. COOKE, *Administrator,*
Rural Electrification Administration.

CONTENTS

For sale by the Superintendent of Documents, Washington, D. C. - - - - - Price 15 cents (paper cover)

As A NATION we not only enjoy a wonderful measure of present prosperity but if this prosperity is used aright it is an earnest of future success such as no other nation will have. The reward of foresight for this Nation is great and easily foretold. But there must be the look ahead, there must be a realization of the fact that to waste, to destroy, our natural resources, to skin and exhaust the land instead of using it so as to increase its usefulness, will result in undermining in the days of our children the very prosperity which we ought by right to hand down to them amplified and developed.—
THEODORE ROOSEVELT, *Seventh Annual Message, December 1907.*

MEN AND NATURE must work hand in hand. The throwing out of balance of the resources of nature throws out of balance also the lives of men.

* * * * * * * *

We think of our land and water and human resources not as static and sterile possessions but as life-giving assets to be directed by wise provision for future days. We seek to use our natural resources not as a thing apart but as something that is interwoven with industry, labor, finance, taxation, agriculture, homes, recreation, good citizenship. The results of this interweaving will have a greater influence on the future American standard of living than all the rest of our economics put together.—
FRANKLIN D. ROOSEVELT, *Message to the Congress transmitting the Report of the National Resources Board and the Report of the Mississippi Valley Committee, January 24, 1935.*

Foreword:

LAND AND MAN

IF THE LAND PERISH, HOW SHALL MAN SURVIVE?

Against the wooded hill it stands,
Ghosts of a dead home staring through
Its broken lights on wasted lands
Where old-time harvests grew.

—JOHN GREENLEAF WHITTIER.

THE successors of Columbus beheld a continent of abundance beyond their fondest dreams—a continent rich in land, minerals, and water; in fertile soils, timber, game, fish, and furs. They believed these things to be inexhaustible, and generally their descendants still cling to that belief.

Yet today fur-bearing animals and fish are to be found in quantities only in the more remote localities; and mere fragments remain of the great pine and hardwood forests of the North Atlantic and Central States.

But, you say, there remain the rich soils and the waters! We can no longer afford to be so confident, for there is something wrong, ominously wrong, about these also.

The rains and the snows still come as of old, but often their waters are returned to the seas more quickly, and without our receiving more than a fraction of the benefits they have to offer.

And in many places these waters now flow off the land in such a manner that rich topsoils are being washed into the rivers and the oceans, or blown away for lack of moisture, out of reach and use by man.

Many believe that another century of present trends would leave the United States unable to maintain the agriculture on which her civilization rests; that the United States is not a "permanent country", and is on the way to join decadent parts of China and Asia Minor, once opulent and magnificent, but now stripped of their fertile soils and buried in the dust of destructive exploitation of resources; that if something effective is not done within a generation, it will be too late over numerous large areas, for this earth disease, like some human diseases, can never be cured if neglected during the early stages.

The soil-erosion specialists tell us that the dust storm of May 11, 1934, swept 300 million tons of fertile topsoil off the great wheat plains; that 400 million tons of soil material are washed annually into the Gulf of Mexico by the Mississippi River; that generally water and wind erosion together each year remove beyond use 3 billion tons of soil.[1]

They find that 100 million once-fertile acres of farm land—equal to Illinois, Ohio, Maryland, and North Carolina combined—have been essentially destroyed for profitable farming; that another 125 million acres are seriously impaired; and that another 100 million acres are threatened—all belonging to the best farm lands of the United States.

And further; that the present annual money loss to land owners and to the Nation is not less than 400 million dollars each year; that the annual rate has been increasing; that the cumulative loss may be conservatively stated as already not less than 10 billion dollars; and that, if the wastage is not stopped, in another 50 years the cumulative loss will reach the staggering figures of 25 or 30 billion dollars, equivalent to a loss of $4,000 on each and every farm in the United States.

This is not a loss of income the flow of which can be resumed, but of assets that cannot be recovered, for it takes Nature centuries to make the equivalent of the top soil which

---

[1] Brown snow fell throughout New England on February 24, 1936. Blown 2,000 miles, the powdery top-soil of the Southwest made its first appearance in New England. The U. S. Weather Bureau and the Blue Hill Observatory of Harvard University stated that the snow, which was formed about these dust particles, ranged from amber to reddish brown in color. It was reported that the deposits of dust amounted to about 10 tons per square mile.

U. S. SOIL CONSERVATION SERVICE

Figure 1.—Dead land, destroyed by overcropping, in the southeastern United States.

Figure 2.—Dead land, destroyed by overgrazing, in the southwestern United States.

U. S. SOIL CONSERVATION SERVICE

U. S. BUREAU OF PLANT INDUSTRY

Figure 3.—Dead land in China—once a cultivated valley enclosed by forested mountains.

Figure 4.—Dead land in Mesopotamia—ruins of Babylon, mistress of the once luxuriant Euphrates Valley.

KEYSTONE VIEW CO.

has been swept away—at the rate in some places of 3 to 6 inches in a single season.

In his ruthless exploitation of land and water resources Man has violated basic arrangements in a manner which Nature will not tolerate.

Through countless centuries there has been built up a balanced, fruitful relationship among waters, soils, grasses, and forests. Each dependent on and helpful to the others, they have learned to work together, through physical, chemical, and biological processes, to create and maintain a continent of abundant, useful resources for the habitation and sustenance of Man.

Then came the settlers—vigorous, keen, and intelligent with respect to matters of the moment, but unforseeing and destructive with respect to matters of the future. Unwittingly, for present gains they sacrificed the birthright they believed they were actually increasing for their descendants.

Blindly and ruthlessly they shattered that balance of Nature's forces which created and maintained the land and water resources that they assumed would last forever.

Impoverishment of these resources, in part by unwise selection for use, in part by improper methods of use, has become a real danger.

This danger is a vital concern of everyone. It is as significant to merchant, manufacturer, and banker as to those who work immediately on the land. Nature's gifts are the basis of all economic life. All conversion and interchange of goods rest on the application of human activity to the earth's materials. This is the basic reality.

Progress or decadence of a people is determined by the manner in which it accepts and utilizes these gifts of Nature. Soils and waters may be so used as to remain permanent assets yielding a perpetual income. On the other hand they may be destroyed as sources of income; may even be so used as to make them essentially self-destructive. A people must choose.

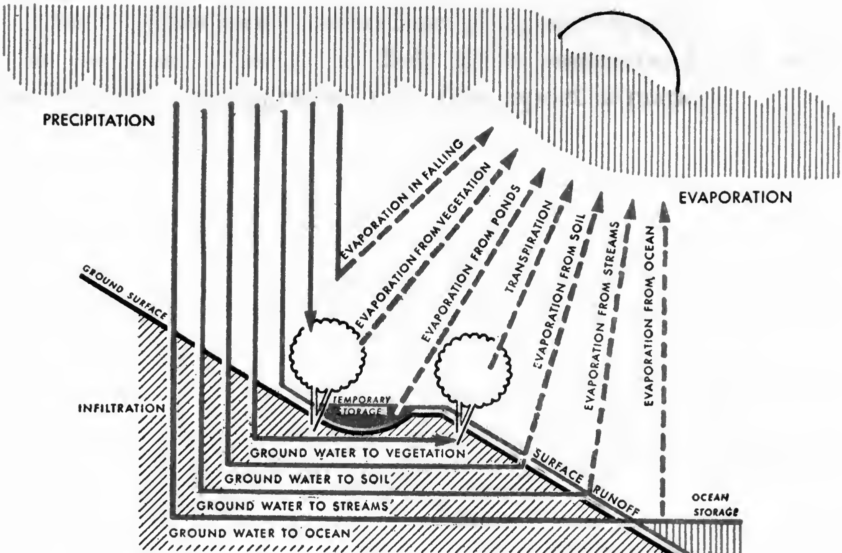
It is with these things that this report is concerned: The balance of forces which through centuries has been patiently and painstakingly developed; the things that Man has done which impair it and diminish the abundance it has created; the things which must be done—now, before it is too late—to recreate the heritage that each generation receives in trust for its successor.

Many of the things that must be done are little things—things each citizen can do and small communities can do—things little in themselves but vital, urgent, and far-reaching in combined results.

Therefore, the matters here discussed are not to be dismissed lightly, as the concern only of engineers, financiers, and governments.

Every citizen must understand and play his part.

It is to all citizens, to help them understand and act, individually and together, that this report is made.



THE HYDROLOGIC CYCLE

I

PATIENT NATURE

A HARMONY OF FORCES FOR THE BENEFIT OF MAN

It were happy if we studied nature more in natural things; and act according to nature, whose rules are few, plain and most reasonable.

—WILLIAM PENN.

IN THIS section we are concerned primarily with Nature's basic arrangements unmodified by the practices of Man. Air, sunlight, soil, and water are the four factors absolutely essential for Man's existence. There must be air to breathe. Sunlight is essential to higher forms of plant and animal life. The soil and its elements provide the materials for food, clothing, and shelter. Without water, Man, animals, and plants could not live, and the soil could not produce food, clothing, and shelter. Man could survive without metals, although his civilization would still be that of the stone age; but if air, sunshine, soil, or water were lacking, he could not even exist. If their quantity or quality were seriously impaired, existence would be difficult.

Broadly speaking, air and sunshine are beyond the influence of Man, but the benefits of land and water can be affected by the manner in which he uses them. Civilization is most secure where soils are fertile, water is abundant, and both are properly used. The highest civilization is realized, of course, where metals are added to these, but a metal culture must have a land-water culture as its foundation.

It is therefore important that we give attention to wise use and conservation of soil and water resources; observe how they have been brought into a relationship in which each makes the other more useful; consider whether we are impairing this relationship; and if we are, take steps to correct any serious harm we may be doing to basic arrangements and therefore to our civilization.

The waters to which we shall here give attention are little waters—rainfall, water in the soil, rivulets that flow off the land, creeks and other headwater streams, ponds, and small lakes—not great rivers and their major tributaries. A river system is like a tree with its trunk, large branches, small branches, smallest branches, twigs, and leaves. It is with the leaves, twigs, and smallest branches of a river system that we are here concerned.

In the aggregate these little waters are of immense importance. They create the big rivers and lakes. As they are controlled and made to behave, so in considerable measure will the tributaries of big rivers be controlled and made to behave.

1. THE NATURAL CIRCULATION OF WATERS

The total quantity of water in, on, and about the earth is believed to be fairly constant, but it exists in various forms and places; as liquid or ice in the oceans, lakes, rivers, and other surface waters; as liquid or frost in ground and underground storage; as clouds, fogs, mists, and vapors in suspension in the atmosphere. It changes from one to another of these forms and moves from one to another of these places.

In their major aspect earth waters have a natural circulation (the hydrologic cycle), in bare outline essentially as follows:

a. The atmosphere absorbs water from oceans, lakes, rivers, the land, and other exposed surfaces—even from falling raindrops—(*evaporation*), and also that drawn from ground storage and exhaled by the leaves of trees and other vegetation (*transpiration*). Few people know what quantities of water are transported by evaporation and transpiration.

Under varying conditions evaporation may lower a reservoir of water 15 inches (Ontario) to 8 feet (California) or even 12 feet (Egypt) in a year.[1] A given area of conifers will transpire the equivalent of from 3 inches (pines) to 8.5 inches (spruces) of precipitation on that area; of hardwoods, from 5 inches (oaks) to 10 inches (beech).[2]

b. Moisture-laden air is cooled as it moves upward, or as it comes in contact with other cooler bodies of air, and the moisture is dropped in the form of rain or snow (*precipitation*). Fogs and dews are also forms of precipitation.

c. Generally the precipitated water, when it strikes the surface of the land, is absorbed and held by the surface soil (*absorption*), and when the water content of this layer has reached a certain point, depending on soil conditions, any surplus penetrates by gravity to underground strata of soil, gravel or porous rock (*infiltration*) where it is stored as *ground water.* The surface of this underground reservoir is called the "*water table.*"

d. When the rate of precipitation is greater than the rate of absorption and infiltration, part of the water runs along the surface of the ground directly into creeks and rivers, and thence into the lakes and the oceans. This is called "*surface run-off.*"

Thus absorption, infiltration and run-off are related. Run-off varies according to the combination of such factors as intensity of precipitation, duration of precipitation, and the absorption and infiltration capacity of the soil. Absorption and infiltration vary according to numerous factors which determine soil characteristics and conditions. With respect to absorption and infiltration there are two dividing points: (a) the soil surface which acts like a sieve and separates surface run-off from absorption and infiltration; (b) the absorption capacity of the top soil, which does not permit water to pass downward to underground storage until the top-soil reservoir is filled to its field-moisture capacity, a point generally considerably below the point of saturation.

[1] Robert Follansbee, Evaporation from Reservoir Surfaces in *Proceedings of the American Society of Civil Engineers*, Vol. 59, No. 2, February 1933, pp. 258–262.

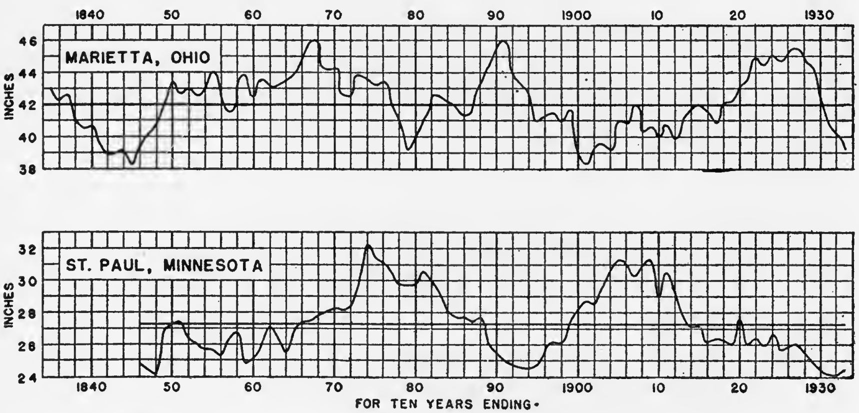
[2] Unpublished manuscript by Oran Raber, Water Relation of Trees with Special Reference to the Economic Species of the North Temperate Zone, Forest Service, U. S. Department of Agriculture.

It is, as we shall discover, largely by acts which decrease absorption, infiltration, and the ground-water store, and which accelerate run-off, that Man has seriously disturbed natural arrangements and harmed himself.

e. Water exposed on the surface of the oceans, lakes, rivers, and land, including that transpired by vegetative cover, is again absorbed into the atmosphere and the natural circulation is continued indefinitely.

The relative quantities of water in these various sectors of the hydrologic cycle may vary greatly, in a manner not yet understood. Seasons follow one another with due reg-

TEN YEAR MOVING AVERAGES OF ANNUAL PRECIPITATION



Prepared from data by J. B. Kincer, U. S. Weather Bureau.

Figure 5.—Ten-year moving averages of annual precipitation. Note the alternating periods of greater and lesser precipitation.

ularity. Generally in each area there are periods of precipitation, alternating with periods of relative drought; but beyond these facts of common knowledge our information is not yet sufficiently definite to permit long-range forecasting. It may be known that in a particular region some snow is certain to fall in the winter season, and that spring and fall will be the rainy seasons, but science cannot predict how much snow or how much rain will fall in any future season. The laws of these relations are not yet known.

A few data have been accumulated which suggest rather than prove that there may be, in parts of the United States at least, somewhat regular long-run variations in precipitation. The curves of rainfall in figure 5 are from two stations at which records have been kept for considerable periods. They suggest that there may be regular alternations of periods of greater and of lesser precipitation. It should be observed, however, that the spans in these curves of annual precipitation vary greatly—from about 25 to 50 years; and what is perhaps more striking, that for areas so close together, relative to the entire United States, as Ohio and Minnesota, at any particular time the precipitation characteristic of one is the opposite of that of the other.

Attention should be directed especially to the importance to Man of the store of ground water. It is less visible and measurable than precipitation and the surface waters, and therefore less commonly understood, but there is nothing essentially mysterious about it. Its importance can hardly be overestimated.

As absorption and infiltration proceed during precipitation, the penetration may be at first quite rapid. It becomes slower as the surface soil becomes puddled and partially sealed, and as pores, sun checks, and earthworm and root perforations are closed by fine particles and the swelling of colloidal material in the soil. It will also be slowed if it reaches a more impervious layer. Continuing to move down and laterally, eventually it strikes impervious rock or other materials, and if there is a sufficient supply, fills the underground porous masses completely. Here it is held as in a great reservoir, from which generally there is leakage along porous strata which permit much of the water again to find the surface through seeping and springs. As the late Allen Hazen has said: "the most instantaneous and effective of all fresh-water reservoirs is the soil.[3]

"Even in the better-watered sections", says W. J. McGee—

the rainfall during the growing season seldom suffices for the production of a full crop, so that generally the productivity of this country is essentially dependent on the water stored in soil and subsoil and underlying rocks within reach of draft by the growing plants. Moreover this store is the chief source of springs and streams whence animals drink; it is the supply

[3] Flood Flow, New York 1930, p. 154.

for wells whence men take the water required for domestic use; and it is the reservoir which holds storm waters and equalizes the flow of brooks and rivers.[4]

We may add that also it is the source of a large part of the increasing quantity of water used by industry, and, perhaps most important of all, that without this store to draw upon the vegetation which provides food, clothing, and shelter generally could not exist.

"It appears", says Robert E. Horton—

that with extensive ground-water storage there is a very definite relationship between ground-water level and stream flow in the absence of rain, whereas in certain other classes of areas, owing either to a lack of permanent ground-water table or to complicated ground-water conditions, there may be but little relationship between ground-water level and stream flow. Areas where the relationship exists are, however, of wide extent * * *.[5]

Most persons will perhaps be surprised to learn how large a portion of the total run-off of streams in permeable soils, such as prevail in the Upper Mississippi Valley, is derived from ground water.[6]

This is rarely less than 40 to 50 percent even for streams with shallow soils, and may run close to 100 percent in the case of streams whose basins are covered with deep, sandy, glacial deposits, such as occur in large areas in Michigan, Wisconsin, and Minnesota.[6]

Natural absorption, infiltration, and maintenance of underground storage are of critical importance. This is not only because of the value of the underground store itself. If the normal process of providing that store through absorption and infiltration is not maintained, excessive run-off will result, and this in itself may do serious damage to Man's interest through the washing away of fertile top soils, a problem to be considered in a later section. Therefore special provision appears to have been made for encouragement of absorption and infiltration by the relations established between vegetative cover and these functions.

---

[4] Wells and Subsoil Waters, *Bulletin No. 92*, Bureau of Soils, U. S. Department of Agriculture, Mar. 26, 1913, p. 8.

[5] The Field, Scope and Status of the Science of Hydrology, in *Transactions, American Geophysical Union*, Twelfth Annual Meeting, Apr. 30–May 1, 1931, p. 199.

[6] Unpublished manuscript, Interrelations of Ground-Water, Rainfall, Run-off, Floods and Soil Erosion, with Special Reference to the Upper Mississippi Valley, March 1934.

U. S. NATIONAL PARK SERVICE

Figure 6.—Beaver dam and pond. On many little waters man-made dams of similar construction are suitable.

Figure 7.—Artesian well. Water flowing through porous strata is forced to the surface by the pressure of a distant underground reservoir at a higher level.

U. S. BUREAU OF AGRICULTURAL ENGINEERING

U. S. FOREST SERVICE

Figure 8.—Virgin forest. Litter, humus, and roots check run-off and promote absorption and infiltration.

2. THE RÔLE OF VEGETATIVE COVER

Let us assume for a moment an earth different from that which we know. If the surface consisted entirely of hard, granular materials such as gravel and sand, free from decomposed organic matter, then absorption, infiltration, and the ground-water store would be at a maximum; and seepage, the discharge of springs, and the flow of streams more regular. Conditions would be suitable for the freest and most rapid circulation of waters. But if to these materials there is added matter in the form of dust, or that swells when wet, precipitation will wash the fine particles into the spaces of the granular structure or cause them to swell. In this way absorption and infiltration are retarded by a clogging of the channels of penetration. Therefore, assuming such an earth surface, if may be said that vegetative cover, the principal source of organic matter (humus) in the soil, retards absorption and infiltration and affects unfavorably the free circulation of waters.

However, that is not the kind of earth with which Man is concerned. Whatever the condition of other planets, the earth is a place of organic life—vegetation, animals, Man. From the point of view of his problems of use and conservation of natural resources, he must deal with surface soils of which some have been pulverized to the consistency of dust and of which most contain organic matter. While there are many spots of sand or gravel, the soils which are most suitable for the production of food, clothing, and shelter are generally humified soils.

Given this earth of humified surface soils necessary for the existence of Man, and assuming that the introduction of the humus to basic granular materials may have caused an initial retardation of absorption and infiltration, beyond that point relations between vegetative cover and humified surface soil were arranged in such a way as to promote maximum absorption and infiltration under the assumed conditions.

Figure 9 shows in approximate detail the normal relations between vegetative cover and absorption-infiltration over most areas before Man developed the art of producing more subsistence from a given area by tilling the soil. When the drops of rain reach the earth they first strike the trees and bushes, or the herb and grass cover of the soil. The water

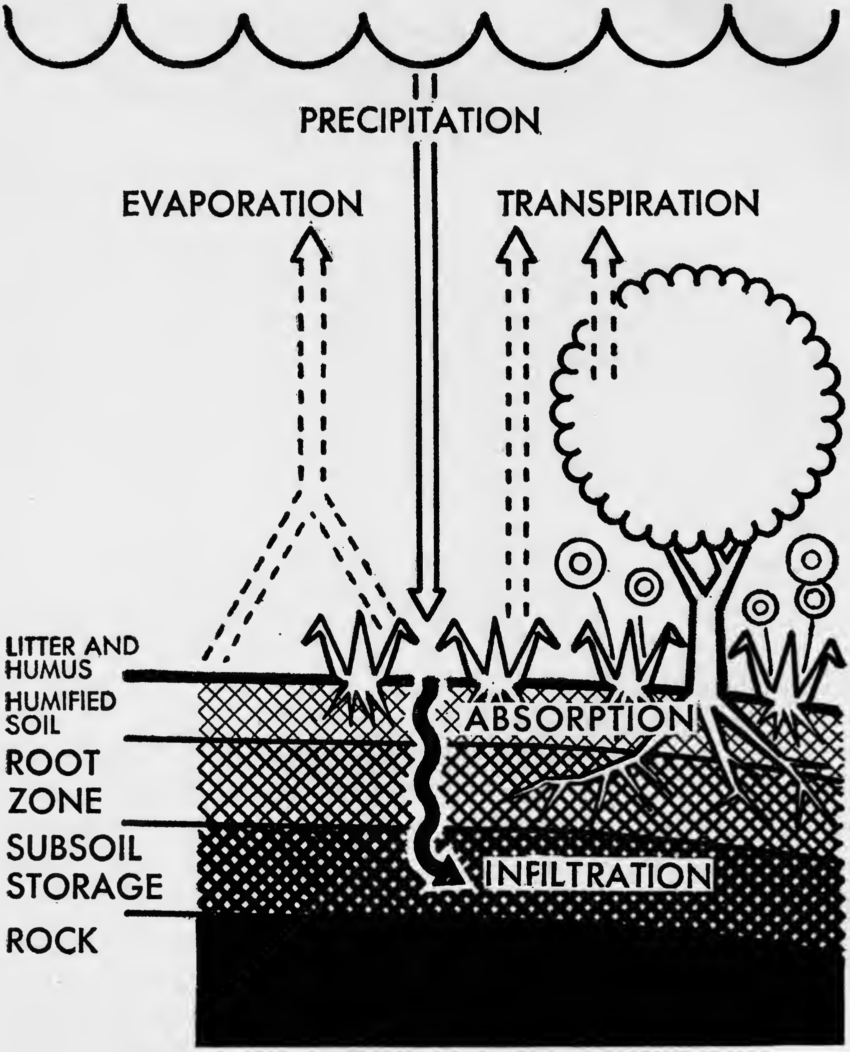


Figure 9.

then trickles through the grass and is absorbed by the loose soil about the grass roots; or, after dropping from the trees and bushes, filters through any forest litter and is absorbed by the loose soil underneath the trees and bushes. When this soil about the roots has absorbed water to a point determined by its characteristics, the water then infiltrates into deeper layers of soil and rock.

Through millions of years there was developed in this manner a "delicate balance"[7] between precipitation, the soil and vegetative cover most favorable to the maintenance of vegetable life, which is the basis of animal and human life.

The part played by forests, grasses, and other vegetative cover in the natural circulation of earth waters is of especial importance. Notwithstanding disagreement among scientists when they consider it in such aspects as influence on climate, rainfall, and stream flow of large rivers,[8] the weight of scientific judgment is that the influence of such cover on absorption, infiltration, and groundwater storage, and on regularity of the flow of creeks and small headwater streams through its influence on groundwater supply, must be a dominant factor in any approach to solution of the problem caused by water and soil losses through excessive run-off. Experiments and measurements have proved that there are noteworthy differences in water and soil losses as between forest or sod lands, lands given to crop rotations, and lands given to continuous, cultivated single crops.

It has been a popular belief that forests and other vegetative cover retard run-off and conserve water primarily because the humus and humified top soil absorb and hold water. These layers do have an important absorptive and holding capacity, although they seldom become completely saturated, and it is by them that the water is immediately provided which carries sustenance to the vegetative cover. But even more important is the promotion of penetration to deeper storage by these layers. The forest litter and the grass mechanically retard flow and hold back water for absorption, their coarseness promotes penetration, they serve as a filter which holds back most of the particles that might clog the soil pores, and their presence as a blanket keeps the underly-

---

[7] W. J. McGee, Wells and Subsoil Water, *Bulletin No. 92*, Bureau of Soils, U. S. Department of Agriculture, Mar. 26, 1913, p. 182.

[8] For a brief summary by a leading authority see The Role of Vegetation in Erosion Control and Water Conservation, by W. C. Lowdermilk in *Journal of Forestry*, Vol. XXXII, No. 5, May 1934.

ing soil moist and absorbent. The humus increases porosity in a soil not only by a physical influence, but also by a chemical influence that promotes aggregation of soil particles (tilth), and by harboring worms and other soil fauna and bacteria. The roots of the trees and other vegetation open channels for penetration into the deeper ground reservoir. This function of vegetative cover to act as a mechanical retarding agent, and to keep the surface open for absorption and infiltration, is of major importance and should be kept in mind, for we shall find that it is the basis for most of the arrangements made by Man for conservation of soils and water where he has removed the vegetative cover.

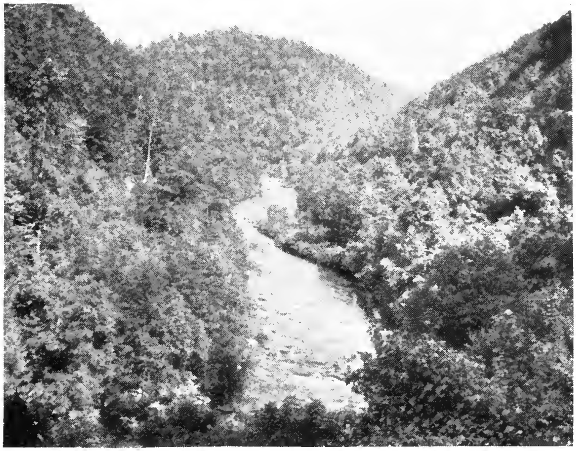
As is the case with respect to all natural arrangements, exceptional situations may be found. Measurements have discovered, as should be expected, that in places where a rock stratum is near the surface and the permeable soil is shallow, a vegetative cover may transpire into the atmosphere more water than it conserves in the manner noted above. Under such circumstances there may be less run-off from seepage during the dry season with vegetative cover than without it; the water held in the root zone is transpired and evaporated before it can seep into the streams.[9]

Generally therefore vegetative cover is an important factor in Man's existence. Without this cover the greater part of the precipitation on other than sandy soils would run off into the rivers, lakes, and oceans; for after a few rains had disturbed, compacted, and caused a swelling of colloidal matter in the soil, there would be left inadequate capacity for absorption and infiltration. There would therefore be little ground-water supply to support vegetable life, and to provide a supply for pumping and for maintenance of the creeks, rivers, ponds, and lakes.

Without this cover there would be another consequence to which only passing reference has been made, although its importance will appear in the next section. The light, fertile soils, soluble or transportable in small particles, would be

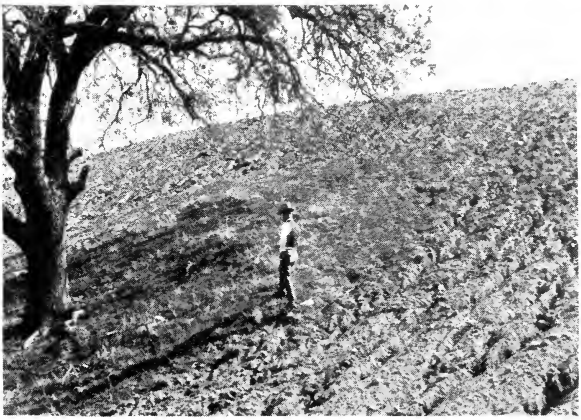
---

[9] Consult W. G. Hoyt and H. C. Troxell, Forests and Stream Flow, *Proceedings of American Society of Civil Engineers*, Vol. 58, No. 6, August 1932, p. 1037.



U. S. FOREST SERVICE

Figure 10.—Mountain stream bordered by steep, wooded slopes which check run-off and erosion and lessen freshets.



U. S. SOIL CONSERVATION SERVICE

Figure 11.—The litter, undisturbed soil, and root system under this lone tree resists the encircling erosion.

U. S. FOREST SERVICE

Figure 12.—Close-up of forest litter—an agent that retards surface flow and filters absorbed water.

U. S. AGRICULTURAL EXTENSION SERVICE

Figure 13.—Natural grass cover; an efficient retarding agent.

U. S. AGRICULTURAL EXTENSION SERVICE

Figure 14.—An ordinary farm pasture helps water penetrate the soil.

Figure 15.—Heavy planted alfalfa promotes infiltration and underground storage, on which it draws heavily.

U. S. AGRICULTURAL EXTENSION SERVICE

washed off the hills and lesser slopes into the streams, or concentrated in valley bottoms, and would be of limited use to Man. This washing away of soils, known as "erosion", is today one of our most serious problems; a problem not found in areas untouched by Man. Normal erosion is a very slow cosmic form—a carving which wears down rock masses and creates soils. There is also a normal creeping of soil masses. But natural forces hold to a minimum, unless it is accelerated by Man's influence, that erosion which consists of wide-spread washing away of soils already made.

3. SOME INTERESTING ASPECTS OF BALANCE

We have given principal attention only to the major aspects of balance between water and land, and among the several forms of water. However, within the frame of these major balances, there are a large number of balances in detail. It will be of interest to note a few of them briefly.

A natural balance of retarded surface flow, underground storage, and seepage from the latter, tends to maintain a fairly regular supply of water in ponds and lakes, and of flow in streams. With this regularity there develops also a balance between water and organic life which provides food for fish and wild fowl, and through these for Man.

Ducks, geese, and other wild fowl thrive on the aquatic plants and other organisms that grow in the water along the shores of ponds, lakes, and streams, and in swamps, marshes, and other wet lands. These fowl tend to disappear when water bodies dry up or become irregular in level or flow, because that balance of relations between water and land along the shore line is upset and conditions become unfavorable to propagation of the organic life on which wild fowl feed.

Fish, a more universal and important food for Man, subsist upon larvae and micro-organic life, which subsist upon decaying vegetation, which in turn is present only when there exists a proper balance of water and soil relations for its growth. Fish tend to disappear from bodies of water that have great irregularity of level or flow, or are polluted by man-made wastes that destroy organic life because the water at times is not in sufficient volume to digest, neutralize, and dissipate these wastes.

Along the sea shores near the mouths of rivers is a border of water less salty than that of the ocean, a border of balance between ocean water and fresh water flowing from the land. This border of balance is a habitat for fish of special value to Man—oysters, clams, lobsters, shrimps, and small fish.

This value arises not alone from the unique flavor of these fish, but also from the fact that they have an exceptional capacity to transform mineral iodine, copper, magnesium, and other health-giving minerals into forms easily assimilated by the human body.

These health-giving fish foods can exist only in the borders of balance between salty and fresh water. This is because, on the one hand, although they could live in the more salty water, their principal enemies cannot live in the less salty water; and on the other hand, because they thrive principally on the organic life of the alluvial, under-water pastures of soil and organic particles that are brought down to the ocean by the fresh-water rivers.

When the regularity of flow of these larger fresh-water streams is seriously disturbed, as it may be when the regularity of feeder flow from their headwaters is disturbed, the balance of salinity of the less salty border is likewise disturbed, with the result that the fish life peculiar to this border tends to disappear.

Balance in detail may be again illustrated by another aspect of the importance of this border of less salty water. On alluvial soils lying in the estuaries of rivers valuable food plants may be grown—truck gardening. This is because the pressure of the fresh water flowing into the ocean pushes the salty water away from the shore and prevents the salt that would destroy the vegetable crops from seeping into the alluvial estuary soils. Where fresh-water flow has diminished and the pressure become reduced, as at the mouth of the Sacramento River, valuable garden areas have been destroyed by the seeping in of ocean salt.

These few illustrations are suggestive of the innumerable balanced relationships in detail among fresh water, organic life, and soil factors. They indicate the importance of maintaining, to the degree that is practicable, the regularity of storage and flow of fresh waters, from headwater creek to the great river mouth.

The natural balance of land and water forces does not represent complete balance and perfectly stable relationships. It represents rather a broad frame of balance within which many variations occur. On the whole, however, the play of forces is such that there is established a maximum interplay and conservation of soils, waters, and vegetative cover.

In Nature there is not, for instance, special provision for prevention of floods, either on the little waters which concern us here, or on great rivers and their major tributaries. On the whole they are accepted. But under undisturbed natural arrangements floods apparently have a lower crest because of retardation of flow, and the amount of water in streams is greater during dry seasons than it otherwise would be. These arrangements may even influence the magnitude of major floods on large rivers caused by an abnormal combination of water-soaked soils and heavy precipitation on headwater areas so timed as to bring their contributory floods together into one great flood on the main stem of the drainage system. Generally, however, floods are permitted to encroach upon low-lying lands adjacent to the regular channels, and these flood plains are clothed with vegetation suitable to their environment.

The natural factors which have been discussed offered to the first settlers of the United States and their descendants a continent of rich resources and apparently unlimited opportunity. The question arises whether in exploiting these resources they have also conserved them, that is, used them wisely; or whether they have so upset the natural balance of forces as to destroy resources which when in balance are essentially indestructible, and have thereby put in jeopardy the maintenance of that high standard of living to which the people of the United States have become accustomed.

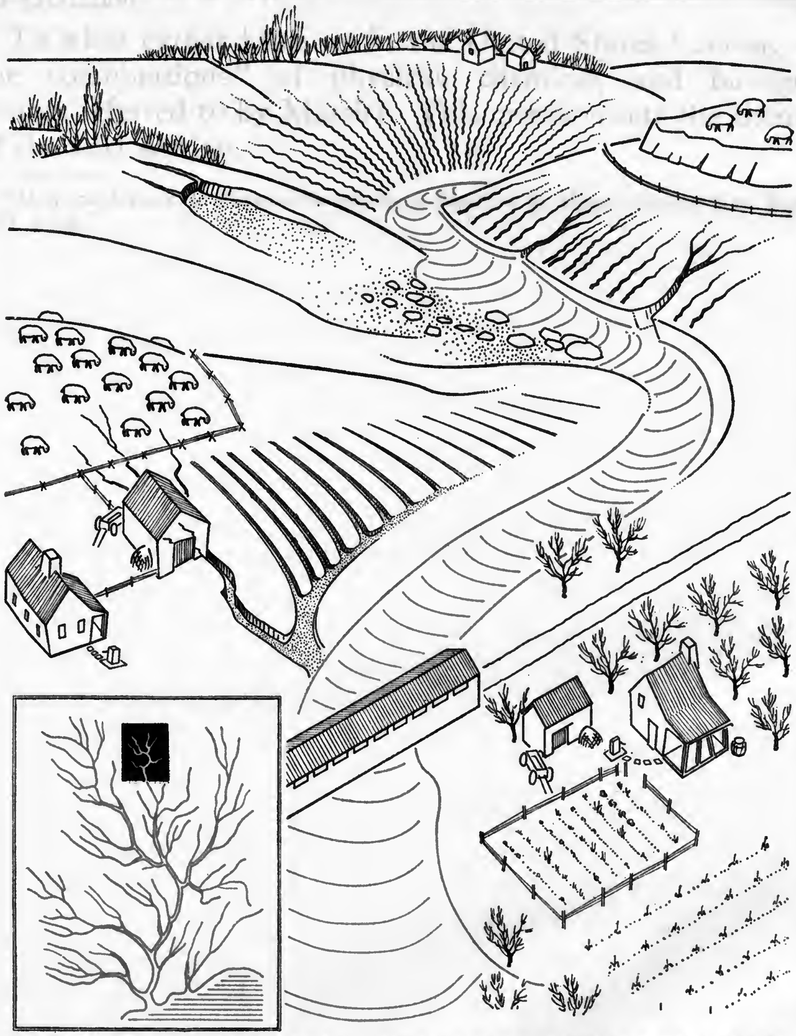
Half a century ago George P. Marsh wrote:

> Nature has provided against the absolute destruction of any of her elementary matter, the raw material of her works * * * but she has left it within the power of man irreparably to derange the combinations of inorganic matter and organic life, which through the night of aeons she had been proportioning and balancing to prepare the earth for his habitation * * *[10]

To what extent have we in the United States "deranged the combinations" of physical, chemical, and biologic factors referred to by Marsh? This question sets the theme of the next section.

---

[10] Man and Nature; or Physical Geography as Modified by Human Action, New York, 1864, p. 35.



HEADWATERS UNCONTROLLED

II

IMPETUOUS MAN

AX AND PLOW BREAK THE HARMONY OF FORCES

When you deal with nature, only the square deal is worth while.
—JOHN BURROUGHS.

THE general balance of land and water factors explained in the preceding section has in the United States been seriously impaired, especially by the methods of agriculture, grazing, and forest abuse. This has become so serious that prosperity has declined permanently in many localities and there is danger of ultimate general decline. We have gained a relatively good living, but at the price of losing the permanence of the resources from which come our bread and butter, and of losing that quality of natural beauty which has been a spiritual inspiration for many generations.

This has not been the intention of those individuals who are responsible. Their activities have to them appeared to be, and from the short-time point of view have been, beneficial to them individually, and therefore they believed to the United States as a whole. But only too frequently in matters of this sort, what is immediately beneficial to the individual and even to the society of which he is a member when only a few engage in the practice, may, when many engage in the practice, become harmful to the whole and therefore by reaction ultimately to the individual. For instance, in a sparsely populated country freedom to hunt and fish at will in all seasons may be a benefit to the individuals concerned, but in a thickly populated country the same freedom soon results in destruction of all useful wildlife. Likewise, practices in respect to the development and use of water resources which in an earlier period of sparse settlement were an advantage to the individual and did no harm to his society, have in a later period of denser settlement proved to be destructive and harmful. In a sparsely settled section of the upper Mississippi Basin a few farmers may turn their prairie sod cover under, and a few small lumber companies remove the forest cover from small areas, with profit to themselves and without disturbing the natural balance in the basin; but when with denser settlement these practices become wide-spread, the natural balance may become so upset as seriously to impoverish or destroy outright those physical characteristics on which prosperity is based. It is our purpose in this section to indicate the more important practices in numerous areas of small headwater streams which have upset Nature's balance of factors and now endanger the prosperity of the United States.

1. RUSHING THE WATERS TO THE SEAS

Before the United States was discovered and settled, Nature through many thousands of years, as has been explained, employed every possible device to promote absorption and infiltration of the rains and melting snows. Grasses, herbs, shrubs, trees, rotting logs, twigs, leaves, stones, and pebbles were retarding instruments; grass, herb, shrub, and tree roots kept the surface soils porous and permeable; the humus blanket kept many soils readily absorbent. Low-lying flat lands became swamp, marsh, or wet lands; pockets and depressions in the sloping surface became ponds and lakes; the underground became a great reservoir. These agencies served to retard the flow of water to the seas, to extend the duration, increase the evaporation, and reduce the crests of floods, and in dry seasons to sustain by springs and seepage the normal flow of streams.

Speaking broadly, the first settlers in a forested region selected fertile, high and dry rolling lands; those easiest to clear and make ready for immediate cultivation. Their pressing need was sustenance and some surplus income from marketable crops. Later settlers selected as nearly similar land as was available, but had to accept a larger proportion of wet and denser forest land. The latest settlers had to accept what was left; the most wooded, wet, sandy, or hilly land. Because of their need for sustenance and of the ready market for cereal, cotton, tobacco, and similar crops, the immediate dominant motive was to clear the forests and drain the lands.

Also about the middle of the nineteenth century the Swamp Act was passed by the Congress, whereby, to promote both drainage and flood control, those portions of the public domain which were too wet for cultivation were given to the States in which they lay, with the understanding that the States were to sell them and that the income would be applied to control works. This, together with the granting of land to railroads, which sold them to purchasers who immediately wanted them drained, led to organized drainage on a large scale.

In this period also lumber became an important cash crop, and denudation of the more accessible timberlands within the reach of markets, created by the growth of villages and cities, was accelerated by the operations of large companies.

Thus developed a triple movement which adversely affected the natural balance of land and water factors: Drainage of ponds, swamps, and other wet lands; plowing under of natural sods; and removal of the forest cover with attendant unfavorable influences which will be explained.

The motivating factors were simple and are understandable. The population was increasing rapidly, both naturally and by immigration; land is a possession and a farm is a home; and it is obvious that the greatest immediate benefit to the individual landowner of that generation was improvement of his property.

[*a*] DRAINAGE.

In the more arid half of the United States, west of the 100th meridian, generally organized drainage is of minor consequence, except as it is supplementary to irrigation because of the necessity of avoiding alkilinity and water-logging; the problem there is chiefly one of irrigation. In the North and Central Atlantic States, while there is much individual farm drainage, it has not extensively come under the auspices of organized enterprises. The South Atlantic, East South Central, and West South Central States have many areas reclaimed by organized drainage enterprises, especially in West South Central States, but in these three groups of States only about a third of 1 percent of all farm land is drained by such enterprises. It is in the East North Central and the West North Central States, especially the former, that organized drainage has been developed most extensively. In these two groups of States over 14 percent of all farm lands is drained by collective enterprises, not including the important item of individual farm drainage, which reaches considerable proportions and is the dominant type in some States, such as Iowa.

It should be at once indicated that on the whole, from the point of view of making productive land available, drainage has been very beneficial. It has improved tillable land and has brought millions of acres of otherwise untillable land—some of it very productive—under cultivation. But on the other hand, it must also be indicated that a considerable amount of this drainage has not been selective, especially that of organized drainage enterprises, of which many were induced by public policies to become highly speculative. These have brought what have proved to be marginal and even submarginal lands into use, have created many problem spots in the agriculture of the United States, and in too many localities have had a wide-spread unfavorable influence on some of the basic hydrologic balances.

In addition to drainage operations on behalf of agriculture, other types of drainage have promoted the rushing of waters unused to the seas. Modern highway and railroad construction includes as a basic factor of its technique an adequate provision for drainage; and carefully constructed ditches along the highways, and culverts wherever needed, have

U. S. BUREAU OF AGRICULTURAL ENGINEERING

Figure 16.—Typical open farm ditch, which may be fed by undersurface tile as well as by surface drainage.

U. S. BUREAU OF BIOLOGICAL SURVEY

Figure 17.—Muck land drained dry and destroyed by fire.

U. S. BUREAU OF AGRICULTURAL ENGINEERING

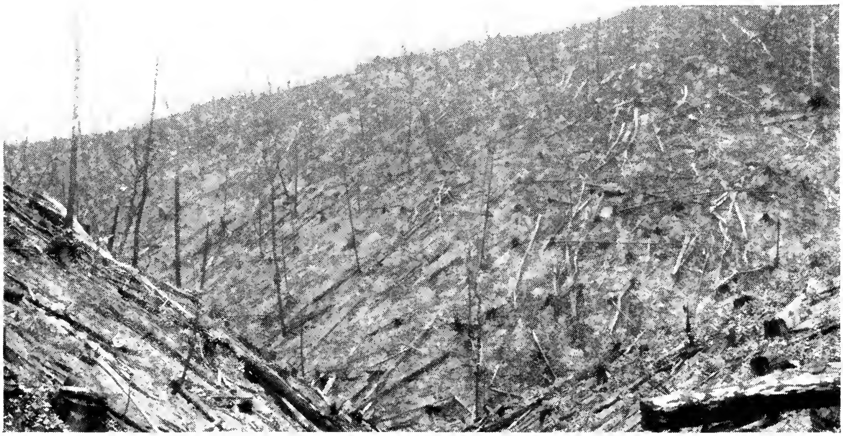
Figure 18.—This large trunk ditch indicates what a vast quantity of water is rushed to the rivers.

U. S. SOIL CONSERVATION SERVICE

Figure 19.—Overdrainage, flashy wet-season run-off, eroded banks; diminished ground-water supply, lessened seepage, scant dry-season flow.

U. S. FOREST SERVICE

Figure 20.—The slashings of a logged area invite fire.



U. S. FOREST SERVICE

Figure 21.—After a fire has destroyed protecting litter, humus, and roots, the top soil is easily washed into the streams.

U. S. BUREAU OF AGRICULTURAL ENGINEERING

Figure 22.—Turning under natural sod cover. Excessive "de-grassation" is a companion evil to excessive deforestation.

caused the disappearance of pools of water following a rain along the rights-of-way. Beneficial from the point of view of the stability of highways, this engineering practice has played its part in hastening the flow of water into the rivers, sometimes incidentally causing increase of run-off and erosion on neighboring farm lands.

Sufficient data are not at hand to indicate the direct influence of drainage on the store of ground water. In the humid eastern half of the United States the average precipitation maintains almost a sufficient store. However, at the breaking point between the humid and arid areas, along a north-south strip in line with the Red River of the North, there has been discovered a considerable drop in the underground water table—from 10 to 30 feet. This is an area pretty well covered by drainage enterprises.[1] Diminution of groundwater supply is the result generally of greater increase of consumption than of supply, and particularly of the run-off of waters to the rivers before they have time to infiltrate—in the words of McGee, "to the cutting-off of the natural source of supply."[2] It is interesting to note that some European countries, older and more experienced than the United States, do not permit drainage into natural water courses of any water that has not served feasible important purposes.

In some localities ponds and lakes have been lowered or have completely disappeared with the drainage of contiguous swampy and other wet lands.

An influence of drainage on the groundwater storage in some areas appears to be the throwing on it of a heavier load by the pumping of supplies for domestic, agricultural, industrial, and other uses, without corresponding replenishment. This appears to have been the influence particularly in the area of the Dakotas, but there are local instances in the more humid east. As ponds, creeks, rivers, and other sources of water have diminished or disappeared, pumping has had to replace the lost source. It should be here noted,

---

[1] Report of National Resources Board, 1934, p. 309.

[2] W. J. McGee, Wells and Subsoil Water, *Bulletin No. 92*, Bureau of Soils, U. S. Department of Agriculture, Mar. 26, 1913, p. 182.

however, as will be explained later, that in those same areas wide-spread removal of vegetation and unwise tillage practices have had an even greater influence by restricting infiltration and promoting run-off.

Another aspect of nonselective drainage over a large area is the effect on stream volumes during the months of lesser rainfall. In some areas, with the disappearance of the swamps, marshes, and other wet lands, and diminution of groundwater stores, which once gradually fed their waters to the streams by seepage and springs throughout the dry season, the waters of these streams have tended to become low during that season, and in some instances entirely disappear. This has created serious problems of pure water supply for agricultural and municipal uses, and of excessive pollution of streams no longer sufficient in flow to carry the burden which public works placed upon them at a time when their capacities appeared adequate.[3]

Collateral to the damage done by drainage through its cutting off part of the natural source of groundwater supply, is the damage done in respect to other services of surface waters. Fish in accessible fresh-water streams have for this among other reasons all but disappeared; and the availability of these streams for recreation has diminished. The wild fowl, once so abundant, are having increasing difficulty in finding breeding, feeding, and resting places, and as a result of the consequent segregation are diminishing in quantity. If for no other reason, a part of the drained submarginal and marginal lands should be restored to some degree of wetness in order to replenish and sustain the diminishing wildlife.

[*b*] REMOVAL OF FOREST COVER.

Of the original forest area of 816,158,000 acres in the United States only 494,898,000 acres remain. Of the cleared area a very large part is in pasture, but also a large part is more or less intensively tilled and cropped. The way has thus been opened for a considerable influence on the circulation of waters by removal of natural vegetative cover.

---

[3] On the other hand, measurements in Iowa show no relation between drainage and stream flow. See Sherman M. Woodward and Floyd A. Nagler, The Effect of Agricultural Drainage Upon Flood Run-Off, *Transactions of American Society of Mechanical Engineers*, 1929, Vol. 93, pp. 821–839.

Science has not been able to determine what has been the precise influence of the removal of forests on the natural circulation of waters. Where vegetative cover is completely removed there is lost the transpiration and evaporation which are believed by many authorities to have considerable influence on the formation of clouds and on temperature, and therefore possibly on the volume and distribution of rainfall. It has been estimated that, depending on regional climatic conditions, a given store of water which has been blown in over the land from the ocean in the form of clouds may be "worked" three to five times as rainfall, because of alternations of evaporation and transpiration with precipitation, before it returns to the ocean as stream flow. Data are not available to warrant a definite statement concerning this phase of the hydrologic cycle.

The influence on absorption, infiltration, the groundwater, and run-off is more observable and measurable. Lumbering operations are immediately followed in most instances, if no other force intervenes, by rapid growth of brush and saplings. The roots, litter, and humus tend to protect the capacity for absorption and infiltration. Therefore, under the assumption that no other force intervenes, the removal of standing timber, generally speaking, has only moderate, if any, unfavorable influence on the absorption and percolating capacity of the underlying humus and soils, and on the mechanical retardation of run-off.

But other forces have been permitted to intervene. In the first place, as has been indicated, a large proportion of the land from which forest cover has been removed during the past hundred years, has been completely cleaned and made cultivable. This substitutes the influence of cultivation on absorption and percolation, which will be considered later, for the influence of forest cover.

In the second place, forest fires have been permitted to devastate cut-over lands. Slashings are especially susceptible to fire, and people are careless about fires in slashings "because the valuable timber has been removed." They do not realize that elements more valuable than the timber—the litter, humus, sprouting bushes, and small trees—have not been removed by the cutting and will be destroyed by a fire. And as the fires spread to uncut areas vast damage is done by destruction of standing timber, underlying shrubs, and especially the litter and the humus under timber, in the soil, and in dried-out peat bogs.

In the third place, in forest, wood-lot, and grass areas, and in cut-over areas that would otherwise have begun to renew themselves, overgrazing has entered as a destructive force. Overgrazing destroys the young sprouts and the grass, exposes the soil to disturbance by hoofs and rain, and thereby to the invasion of erosion.

As soon as the litter and humus are removed by any of these influences, the soils which they have protected and kept open are exposed to the mechanical influence of falling and running water; the surface is sealed by the puddling rains and the action of sheet erosion; absorption and percolation diminish; and the force of the increased run-off washes the soils into the ponds and streams. This sheet erosion is eventually followed by gully erosion, the slopes are stripped in places to the underlying subsoil or rock, the area affected becomes barren waste, and most of the precipitation passes directly to the rivers and the seas. Soils and waters which might have served men are lost.

[*c*] REMOVAL OF SOD COVER.

As important as the removal of natural forest cover, although not as extensive, is the destruction of sod cover. At the beginning of settlement of the United States the areas not occupied by forests—forest openings, valley bottoms, the prairies and the great plains—were covered by grasses and herbs. These grasses and herbs contributed to the humus, kept the soil open and absorbent, served as a retarding influence on run-off and in general promoted infiltration. As population has increased, more and more of these native grasslands have been turned under for cultivation of cash crops; and in many sections of the West they have been subjected to excessive grazing, particularly of sheep, which graze closely and often destroy even the roots of the grass. This thinning of the grass cover subjects these lands to changes which reduce absorption and infiltration and to waste by erosion in the same manner as do fires following deforestation.

In the predominantly grass-covered West North Central States (Minnesota, North Dakota, South Dakota, Iowa, Nebraska, Missouri, and Kansas) and in such Mountain States as Montana, many millions of acres have been converted to tilled land during the past 20 years—many of them to the especially ruinous "dry-farming" of cereal crops. In view of conventional agricultural practices and the greater susceptibility of clean-tilled, single-crop land to erosion than grassland, this increase in the proportion of crop lands has had significant unfavorable influence from the point of view of conservation of soil and of water.

[*d*] TREATMENT OF STREAMS.

Streams also have been treated in a manner which hastens the flow of unused waters to the sea. Many creeks and small headwater rivers have been dredged and straightened to carry off rapidly the waters fed by drainage ditches, and the channels of great rivers have been straightened, deepened and confined to promote navigation, to open fertile flood plains to agriculture, and to reduce flood dangers. The writer can recall a small river of his youth that was 25 to 30 feet across; today it is a straightened cleared ditch barely 8 or 10 feet in width.[4] On this point Aldo Leopold, noted scientist, has written as follows:

> I have just returned from Germany, and I am much impressed by the almost nation-wide error which has been made there in straightening small streams. The prevention of stream straightening by engineers stands out in my mind as one of the imperative pieces of work, and of course the development of any sound policy must probably be preceded by considerable research.[5]

From the point of view of absorption, infiltration, retardation of run-off, and maintenance of the groundwater store, Nature's arrangements in respect to streams were

[4] Shiawasee River, Livingston County, Mich.
[5] Madison, Wis.; letter of Nov. 21, 1935.

57288°—36——3

superior. The meandering stream, twisting and flowing back on itself around bends, clogging itself with logs and other debris that form numerous backwater pools, and permitting its floods to spread thinly over flood plains, is the natural way of reducing velocity and promoting penetration.

[*e*] THE SOCIAL LOSS.

As a consequence of the practices which have shortened the time between precipitation and the return of waters to the oceans, there are serious losses which must be set over against the gains which have induced the practices.

We may sum up the gains as follows: Through drainage, clearing of forests, and plowing under of natural grasslands, a remarkable addition to the tilled lands of the Nation and to the production of agricultural crops has been made. From this must be subtracted the losses resulting from failure to be selective, which resulted in the draining of inferior soils and the creation of social-problem areas. In the background also is the question whether exploitation and productivity may not have proceeded faster than the economic system could adjust to them. However, notwithstanding the failure of these practices to be governed by uniform policies and plans, to be selective, and to have uniformly beneficial results, there remains a noteworthy net gain in the agricultural power of the United States.

With respect to conservation of water assets (we shall consider later conservation of soils), the outstanding losses are: First, a large proportion of the waters precipitated on the land surface find their way to the oceans without having rendered all their potential services to man; and second, in their course they destroy property and frequently human lives.

It is a folk saying that a mill can never grind with the water that has passed. Likewise a people can never receive the benefits of waters that have passed; and their potential serviceability is in the aggregate enormous. Given retardation and more regular flow in the circulation of waters because of adequate ground and surface storage, many communities now deficient may realize one or more of the following bene-

U. S. SOIL CONSERVATION SERVICE

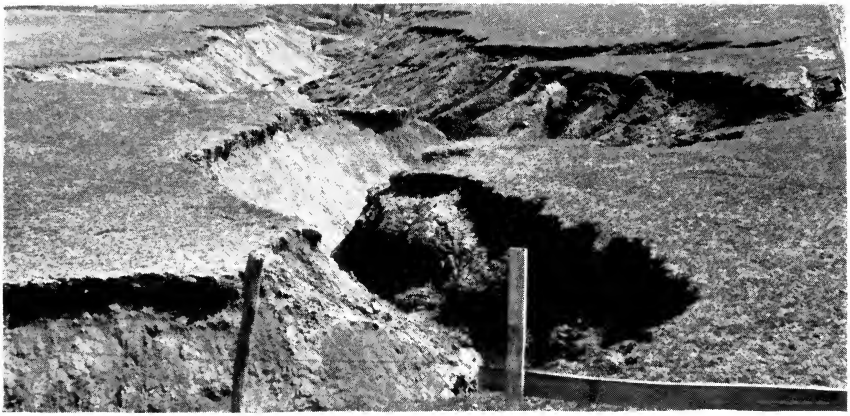
Figure 23.—Sheet erosion and silting; an early stage in the destruction of fertile land. Compare figures 35, 36, 37.

U. S. SOIL CONSERVATION SERVICE

Figure 24.—The beginning of gullying. Compare figure 38.

Figure 25.—Eroded cowpaths have become serious gullies. Compare figures 38, 39, 40.

U. S. SOIL CONSERVATION SERVICE



U. S. SOIL CONSERVATION SERVICE

Figure 26.—Very serious octupuslike spread of gullying. Compare figure 40.

U. S. SOIL CONSERVATION SERVICE

Figure 27.—Eroded beyond restoration.

U. S. SOIL CONSERVATION SERVICE

Figure 28.—The dust storm of May 11, 1934, swept 300 million tons of rich top soil off the great wheat plains.

fits: A larger supply of ground water for growing crops, and of stored and pumped water for supplementary irrigation;[6] pure water at all times for stock in fields and barns, and for domestic use; sewage and garbage disposal in a manner that utilizes aquatic micro-organisms to provide feeding places for grazing species of fish and wild fowl; hydro-power on a large or small scale; navigation; and recreation based on water in an age when recreation is becoming a more indispensable social need. On the negative side the run-off would be less flashy and the damage from floods and siltation reduced.

Not all the apparent gains of agriculture reflected in the statistics of increase of acreage and of production are genuine gains. Most of that which is gain could under wise policies and practices have been realized without such a huge sacrifice of benefits potential in water resources. In addition, as we shall see shortly, there has been an enormous loss of the rich soils of many of the lands that have been opened and tilled—the loss from erosion.

Said George P. Marsh, a half a century ago:

> The vengeance of Nature for the violation of her harmonies, though slow, is sure, and the gradual deterioration of soil and climate in such exceptional regions is as certain to result from the destruction of the woods as is any natural effect to follow its cause.[7]

2. EROSION

THE LOSS of the service of waters and collateral losses to which attention has been called are indeed important, but they represent a loss of income rather than of permanent assets. So long as the total quantity of water about the earth remains fairly constant and the hydrologic cycle continues, ground water, ponds, lakes, creeks, and rivers can be restored. There is, however, another loss resulting from Man's failure to adjust himself to Nature's forces which is an irreparable loss of assets. This is the washing of the top soils essential to agriculture into streams, rivers, and the

[6] See p. 60 for explanation of supplementary irrigation.

[7] Man and Nature; or, Physical Geography as Modified by Human Action, New York, 1864; p. 216.

oceans. It would require centuries for replacement of the fertile top soils that are being washed or blown away in a single generation.

The question whether the United States is a permanent country, first raised some 70 years ago, has been considered fantastic. Recent measurements indicate that it is far from fantastic—is very real and practical—and that one can rationally assert that in another century this great American granary may have become inadequate to support our population if erosion is permitted to continue at the present rate of

EXTENT OF EROSION IN THE UNITED STATES

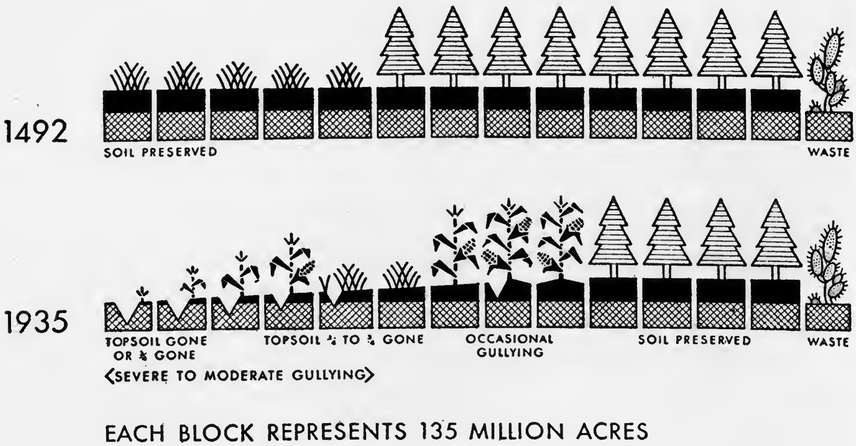


Figure 29.

increase. Already in some sections of the country once cultivated lands have been reduced to sterility.

A deep-rooted but utterly falacious American tradition is that agriculture is inherently a permanent industry. As waters are lost, the soil may be lost. "When the soil is gone, men must go; and the process does not take long," said Theodore Roosevelt.[8] Recent studies indicate that the Sahara and Gobi Deserts were once occupied by prosperous peoples.

---

[8] Eighth Annual Message, Dec. 8, 1908.

In 1864 this question of permanency of a country was brought to our attention as follows:

If the precipitation, whether great or small in amount, be equally distributed through the seasons, so that there are neither torrential rains nor parching droughts, and if, further, the general inclination of ground be moderate, so that the superficial waters are carried off without destructive rapidity of flow, and without sudden accumulation in the channels of natural drainage, there is little danger of the degradation of the soil in consequence of the removal of forest or other vegetable covering, and the natural face of the earth may be considered as substantially permanent. These conditions are well exemplified in Ireland, in a great part

Soil and water losses

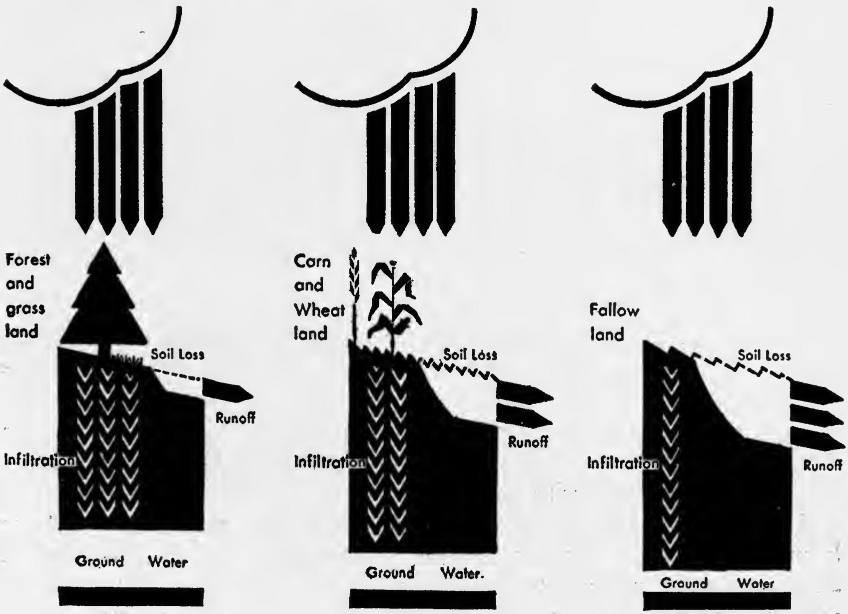


Figure 30.

of England, in extensive districts in Germany and France, and, fortunately, in an immense proportion of the valley of the Mississippi and the basin of the great American lakes * * *.

Destructive changes are most frequent in countries of irregular and mountainous surface, and in climates where the precipitation is confined chiefly to a single season, and where the year is divided into a wet and dry period, as is the case throughout a great part of the Ottoman Empire, and, more or less strictly, the whole Mediterranean Basin. It is partly, though by no means entirely, owing to topographical and climatic causes that the blight which has smitten the fairest and most fertile provinces of Imperial Rome, has spared Britannia (and other northern areas of Europe).[9]

Much of the area of the United States may be classified as belonging to the second type. Generally its climate is such that there are wet and dry seasons, approximately at any rate; in many parts the rains are heavy and at times torrential; and a large proportion of the country—75 to 80 percent—is mountainous or sloping. Even a moderately rolling terrain, when the vegetative cover has been removed and the top soil pulverized by cultivation, is susceptible to erosion, as in many parts of the Mississippi Valley. However, as Bennett has told us, slope is not the most potent factor affecting erosion and run-off. Available data indicate that the most important factor is the character of the vegetative cover, and after that the character and condition of the soil.[10]

The fertile top soils of many of the best agricultural lands of the United States have been or are being washed out of the reach of service to Man as a result of the removal of vegetative cover and the manner in which tilled lands are cropped.[11]

This wastage of the most basic and indispensable resource of the country—the soil—has become one of the most important problems confronting the Nation. From a country with a large proportional area of rich agricultural land we are plunging, almost heedlessly, in the direction of a nation of predominantly poor agricultural land, as the result of unrestrained erosion.

The economic and social aspects of this tragic transformation have been tremendous. The acceleration of erosion * * * has reached an enormous annual cost to the Nation, as measured by soil depreciation and reduced yields alone; and has carried with it consequences of first importance to the permanence of investments in the billions of dollars in navigation, water-power sites, municipal water-supply reservoirs, irrigation developments, agriculture, and grazing.[12]

If we should will to do something designed to arrest this "plunging, almost heedlessly, in the direction of a nation of

---

[9] George P. Marsh, Man and Nature, New York, 1864, p. 49.

[10] H. H. Bennett, Dynamic Action of Rains in Relation to Erosion in the Humid Region, *Transactions, American Geophysical Union*, 1934, pp. 481–482.

[11] See Foreword, p. 2.

[12] Report of National Resources Board, 1934, p. 161.

predominantly poor agricultural land" we must understand the nature and causes of erosion. The beginning of such understanding is to recall the nature of the hydrologic cycle—precipitation, evaporation, absorption, infiltration, run-off, transpiration, and seepage—the relations to these of vegetative cover, and the parts played by humus, humified soil, and the root system.[13]

The most immediate and direct cause of destructive erosion is soil disturbance, that is, a disturbance, of any kind, of the natural balance between gravitation and the binding power of roots, tending to hold the soil in place, and on the other hand the force of running water tending to move it.[14]

SOIL LOSSES THROUGH CULTIVATION

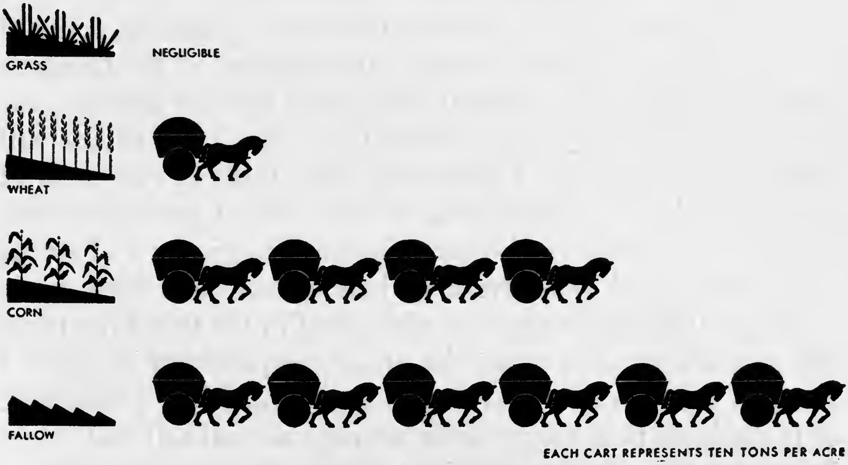


Figure 31.

When forest areas have been cut for their timber and have been left to the almost inevitable following fires, then the litter, humus, and sprouting seedlings are destroyed, accelerated run-off begins to carry away the fertile topsoil, and soon the areas are stripped to the clay, gravel, sand, or rock beneath, and productive lands become waste.

When an excessive number of cattle and sheep are permitted to graze on pasture land, or on native grassland, or in

---

[13] See p. 6.

[14] C. G. Bates and O. R. Zeasman, Soil Erosion—A Local and National Problem, *Research Bulletin 99*, August 1930, University of Wisconsin Agricultural Experiment Station, p. 94.

forest openings, the vegetative cover is destroyed to the very roots, run-off is accelerated, and erosion begins its destructive work.

When the settler cuts his woodland and grubs out the stumps and roots, or when he turns under the natural sod cover; when in addition he cultivates the soil to a powdery state easily carried by even thin sheets of running water; and when he finally arranges drainage so that precipitation is rushed to ditches and the streams; he increases the relative proportion of run-off. This run-off—if he is not a careful farmer in this respect, as most have not been—proceeds not gradually but at an accelerating rate, and carries with it out of the reach and usefulness the fertile top layer of soil which is the farmer's greatest asset. Sheet erosion is the least spectacular but for that reason the most dangerous form of erosion. Gradually the per acre productivity of the farmer's land declines as the elements for plant life are leached out or are carried away bodily with the entire mass of the soil itself; gullies form and eventually the farm is ruined; and progressively the farmer sinks to the level of striving to eke out a meager existence by seeking bread in gravel and stone.

Studies of soil losses from various causes have been made at agricultural experiment stations, and in the following table are reproduced data from the erosion experiment station of the Soil Conservation Service at Bethany, Mo. Inspection of it discloses that the greatest average annual soil and water losses are from fallow (spaded) soils, and the next greatest from continuous single cultivated-crop soils (in this instance corn); while the losses are much less from soils where there is rotation of grass and cultivated crops, and are almost negligible from soils covered continuously with grass or alfalfa. Such exact data give indications of the nature of the agricultural technique, to be considered later, which should be observed by all farmers; one that will result in a rational balance of current income with conservation of soil assets.

No nation, however vigorous it may otherwise appear to be, can survive a progressively declining agriculture. The sustenance it draws from the soil determines its powers of resistance. In a final analysis the food, clothing, and shelter of merchant, manufacturer, and banker come from the land. Their prosperity rests definitely on the prosperity of agriculture.

TABLE I.—*Average Annual Soil and Water Losses, 1931–33 Inclusive, Experiment Station, Bethany, Mo.*[1]

[Shelby silt-loam, 8 percent slope, 33.54 inches mean precipitation]

Item	Soil (tons per acre)	Water (percent precipitation)
CONTINUOUS		
Corn, plot 1	74.09	24.59
Corn, plot 2	60.80	27.41
ROTATION		
Wheat, clover, corn	10.36	10.68
Clover, corn, wheat	7.19	11.57
Clover (fertilized), corn, wheat	3.74	8.64
Average of plots 3, 4, 5, and 6	9.91	11.06
CONTINUOUS		
Alfalfa	.21	3.41
Grass	.32	7.74
FALLOW		
Spaded soil	112.06	26.02
Spaded subsoil	73.47	24.65

[1] Adapted from H. H. Bennett, Dynamic Action of Rains in Relation to Erosion in the Humid Region, *Transactions, American Geophysical Union*, Fifteenth Annual Meeting, 1934, p. 4.

Generally, the immediate responsibility for that erosion which results from methods of farm management rests on those in actual charge of operations. There can be no question about this with respect to those who are both owners and operators. But with respect to those operators who are tenants—and an increasing proportion of farms are tenant operated—the weight of responsibility rests heavily on the absentee owner. The dominant interest of the more or less transient operator is to secure income, and, unless restrained, it is inevitable that he will manage accordingly. On the other hand, although the owner seeks income, he has the equity and his dominant interest should be to preserve his equity unimpaired. It is his responsibility, therefore, to select tenants who will operate in such a manner as conserves the soil. The owner must bring every influence to bear to secure such management; wise selection of tenants, inducements in the terms of the contract—short-term and share leases should be avoided—information, friendly guidance. It is obvious that also creditors holding long-term mortgages have a similar responsibility.

Tenancy, and all that makes for tenancy, is at the root not only of the agricultural but of the conservation problem.

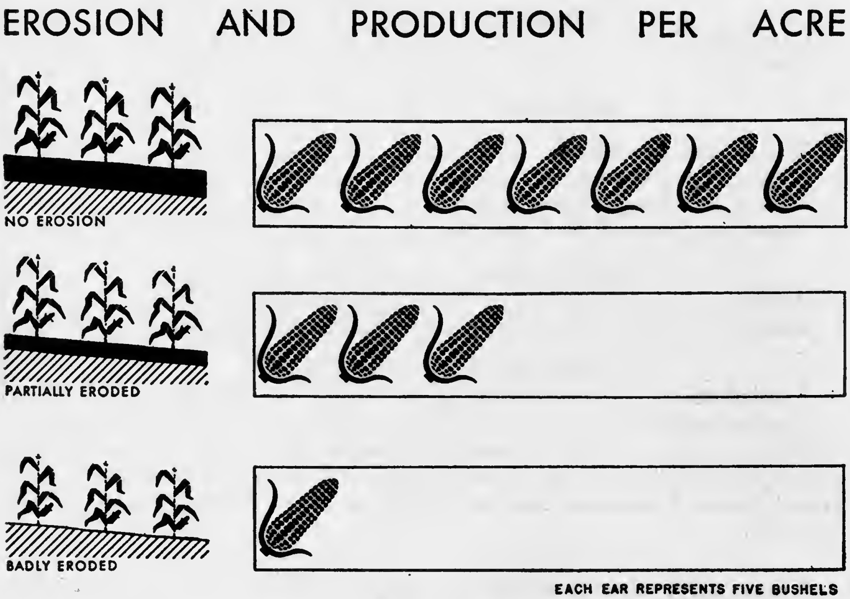


Figure 32.

3. CREEKS, PONDS, RIVERS, AND LAKES

An aspect of drainage policy and practice to which only passing attention has been given is their influence on ponds and lakes, and on creeks and other small headwater streams.[15] Drainage practices have led in places to the disappearance of many ponds and lakes and to the lowering of others; and the desire to reduce the overflow of streams in rainy seasons

[15] See pp. 21 and 27.

has led to clearing and straightening of headwater channels to effect more rapid flow into the larger rivers.

As a consequence some headwater areas have been deprived of a number of beneficial uses of water. The streams and small bodies of water do not contribute as much as formerly to the underground water store, and therefore to the pumping supply. In many areas less surface fresh water is available for domestic and industrial use and for the watering of

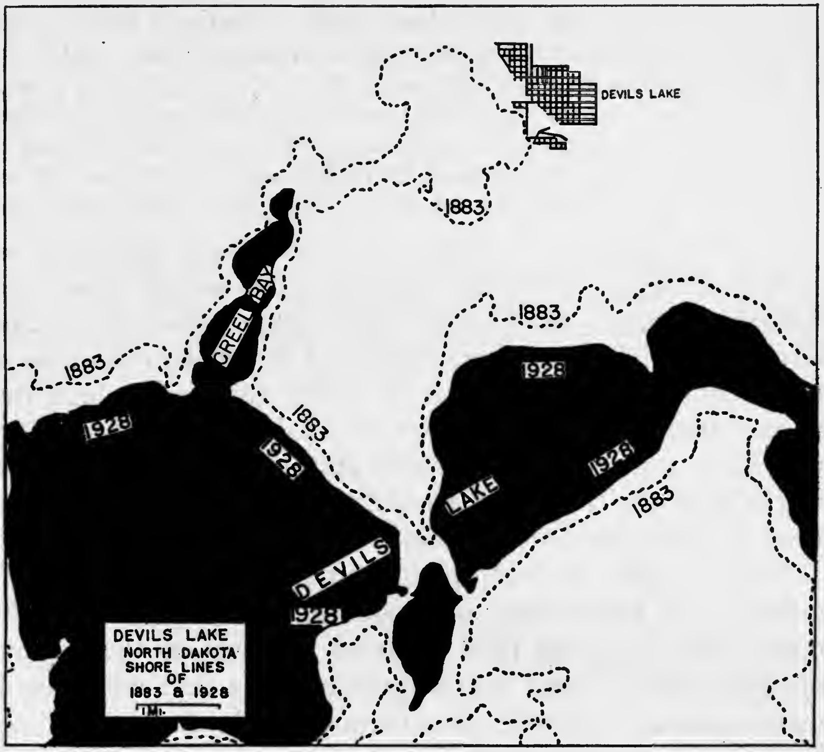


Figure 33.

stock. The diminished volume of flow in the rivers during the dry season is less able to carry and digest sewage and other waste, and the problem of pollution is aggravated. Less water is available for individual-farm, supplementary irrigation. Fish and wildfowl have disappeared from many areas which were once their natural habitat. Water facilities for community recreation have diminished, and the scenic values of water as an element in the landscape have been lost in many places.

Another loss is the disappearance of small power sites, of which many were developed, especially in the Northern States, as settlement spread westward. For instance, in the Muskingum, Ohio, drainage area alone, as reported by the Dayton-Morgan Engineering Co.,[16] in 1880 there were still in existence 253 local water-power mills.

> Coincident with the development of the Ohio canals was the construction of water power saw mills and grist mills. Practically every stream in the Muskingum basin at one time had one or more of these small power plants for grinding flour and feed, for sawing wood, or operating a small shop or factory. As the canals went into disuse these small water power plants also were gradually abandoned, partly because of shortage of water supply and partly because of the ready availability of coal. These early plants were mostly low head, simple, direct connections of low cost.

The disappearance of most of these local plants, even without diminution of the water supply, would have been brought about by the competition of large power plants and large industrial enterprises, supported by efficient systems of transportation; but it is quite as likely that in the long run decentralized generation of power and decentralized industry will have a new and important status in our economy, in which case availability of a regular supply of water in reservoirs on small streams will again become of importance.

There is difference of opinion among engineers as to the influence of headwaters on floods and stream flow in the main stems of great river systems. However, the general opinion in the United States appears to be that while headwater stream regularization through wide forestation can have influence, regularization through creation and maintenance of ponds, backwaters, reservoirs, and lakes can have little influence on the floods of main stems. A nonprofessional analysis of their discussions leads to the strong impression that they are thinking primarily in terms of flood *elimination* rather than in terms of contribution to flood *control*. There appears to be ground for the conclusions: first, that headwaters control cannot *eliminate* floods; but

---

[16] Document issued by Ohio Department of Public Works, 1931.

second, that retardation of flow simultaneously on all headwater streams of a river system will render flood and low-water *control* less difficult on the main stems. This point of view is not without engineering support of highest standing, especially in Europe where experience with works of this kind is much greater than in the United States. The late Allen Hazen, a leading engineer, said:

> Lakes and reservoirs sometimes play an important part in modifying and reducing flood flows in the streams that flow from them. The total flow is not reduced but it is spread over a longer period. Some reservoirs * * * are normally empty and their capacity is always available for holding back flood flows * * *. Other reservoirs have been built to conserve water for navigation, irrigation, power, or public water supply. Such reservoirs will also hold back flood flows but in varying degrees * * *. The meadows along many streams are overflowed at flood stages and this storage capacity tends to reduce the maximum flood flows in the valley below by extending the period of discharge over a longer interval * * *. In other cases there is an important amount of storage in the soil * * *. All storage, whether built primarily for flood control, for development of power, or for any other purpose, will tend to reduce flood conditions * * *.[17]

The question is not one of the influence of a single small creek or mill pond or lake on the flow of the main stem of a great river system, but of the influence on that flow of thousands of marshes, pools, ponds, reservoirs, lakes, creeks, and small headwater streams, combined with agricultural practices that retard run-off and promote infiltration simultaneously throughout the entire headwater area.

While immediate responsibility for the disappearance of watershed ponds and lakes, and failure to regulate headwater streams, must be charged to the motives and practices of the owners of the land and to promotional drainage enterprises, a contributory responsibility must be charged to the engineering profession generally. If the profession had given as much attention to watershed problems as to large river problems, it could have influenced conduct relating to watershed waters, in part by direct educational influence on owners of land and on promoters of drainage enterprises, and in part by stimulation of controlling legislation.

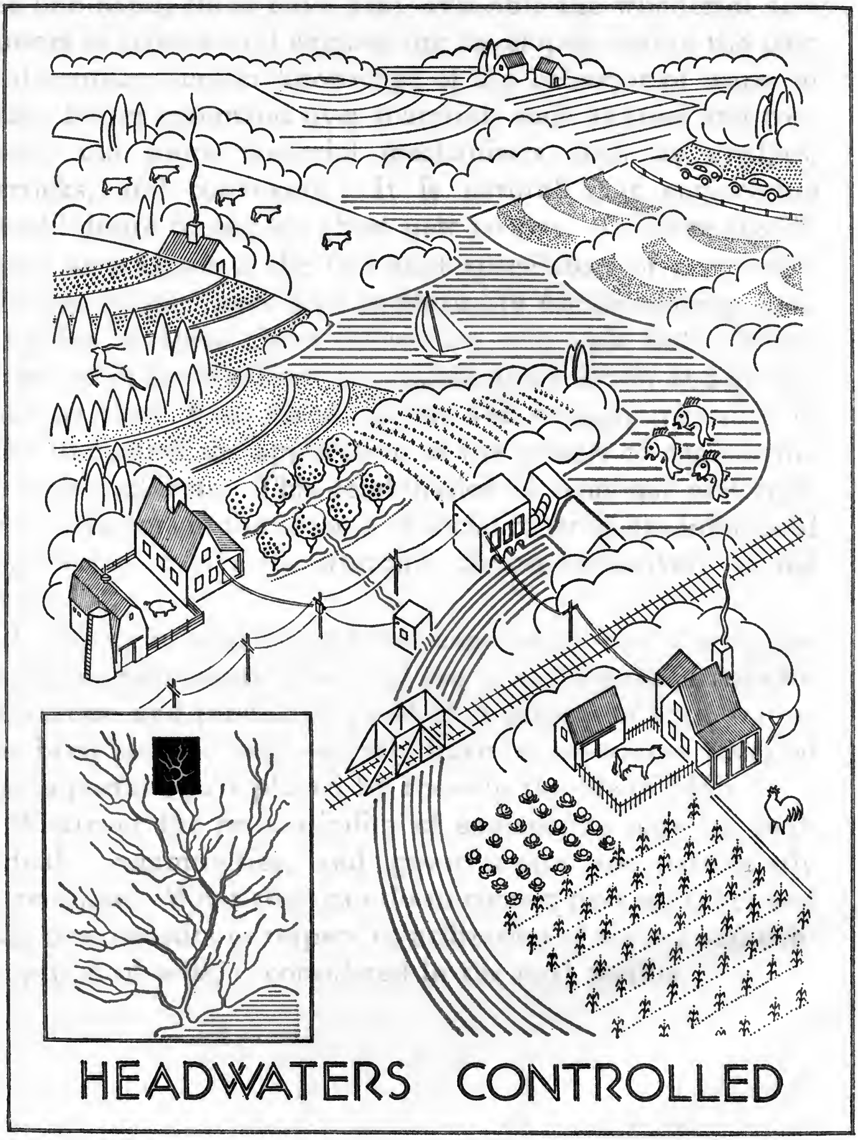
---

[17] Flood Flows, New York, 1930, pp. 149, 150, 151.

During the past half century the attention of engineers concerned with waters has been too exclusively centered on big things—floods and levees and revetments; large-scale hydropower, great dams and reservoirs. This is explicable. On the one hand, there have been available the wonderful new powers of science and engineering developed during the past half century—better knowledge of the behavior of water in mass, better command over materials such as steel and concrete, and more powerful mechanisms such as dredges, derricks, and conveyors. It is natural that engineering should desire to employ these new powers. Of more significance as a factor is the fact that speculators of every conceivable variety have seen opportunity for developing communities in areas characterized by rich soils but without water, or in areas subject to periodic great floods, and groups such as these have clamored for and brought pressure to bear to compel the application of the powers of engineering to their problems. This combination of economic and engineering factors in the absence of social controls has influenced engineering to give its attention almost exclusively to big works.

In justice it must be said that engineering has constructed works of great social value, and has made large areas safe for habitation and production; and that neglect of little waters has been because only recently have its researches revealed the important part played by these in the life of Man.

Whatever the responsibility of engineering may be, individuals, communities, and governments are particularly responsible. What they can do to correct past mistakes and gain new benefits in respect to utilization of waters and conservation of soils, is considered in the next section.



HEADWATERS CONTROLLED

III

MAN AND NATURE, INC.

THE PHYSICAL BASIS OF A PERMANENT COUNTRY

I swear the earth shall surely be complete
to him or her who shall be complete;
The earth remains jagged and broken only
to him or her who remains jagged or broken.

—WALT WHITMAN.

THE injury already done to Man's interests by practices which disturb natural relations between land and water is serious. These practices must be revised promptly. In addition, reparation should be made as speedily as possible. This means that Man must work with Nature's forces; that he must restore the fundamental balances to which attention has been called.

It is obviously impossible for the United States to restore generally the conditions which existed at the time Columbus discovered America. We have a population of 125 million to feed and clothe; this will be increased 15 to 17 million in the next quarter century. To do this a vast area must be tilled. This means, however, a highly selective use of land. Intensive cultivation of carefully selected areas must produce the necessary food and clothing; other areas can then profitably be released for restoration of natural stabilizing and conserving conditions, and incidentally for the production of other items essential to Man's comfort. It means that Man and Nature must set up a cooperative relationship.

A distinguished scientist has said—and when he speaks of the land he refers to all elements of Nature:

A harmonious relation to the land is more intricate and of more consequence to civilization, than the historians of its progress seem to realize. Civilization is not, as they often assume, the enslavement of a stable and constant earth. It is a state of *mutual and interdependent cooperation* between human animals, other animals, plants, and soils, which may be disrupted at any moment by the failure of any of them. Land despoliation has evicted nations, and can on occasion do it again. As long as six virgin continents awaited the plow, this was perhaps no tragic matter—eviction from one piece of soil could be recouped by despoiling another. But there are now wars and rumors of wars which foretell the impending saturation of the earth's best soils and climates. It thus becomes a matter of some importance, at least to ourselves, that our dominion, once gained, be self-perpetuating, rather than self-destructive.[1]

The words "mutual and interdependent cooperation" indicate the key to solution of land and water problems. Nature renders great service to Man by putting vast forces at his disposition. But he must observe certain basic conditions which have been established. He must be cooperative.

These conditions pivot on the natural circulation of waters, and the relations to it of soils, forests, and other vegetative cover.

If the unfavorable trend which has been emphasized in our discussion—

were the result of natural forces at work in an unknown manner, there would remain nothing but to allow blind fate to reign and to consign future generations to their inevitable doom. This is, however, fortunately not the case. * * * It is therefore possible to prevent the threatening calamity or to defer it for an incalculable period of time by a rational effort and by a unanimous, tireless resistance on a suitably large scale.[2]

To know the limitations of rainfall and how our run-off waters behave under varying conditions of climate, cover and topography, and having acquired this knowledge, to apply it with wisdom in making them serve present and future needs most effectively—to aim to make our waters our servant and not our master—is water conservation.[3]

---

[1] Aldo Leopold, The Conservation Ethic, *Journal of Forestry*, Vol. XXXI, No. 6, October 1933, p. 635.

[2] Revision of translation by G. Weitzel, 1881, pp. 5 and 6, of Gustav Wex, "First Treatise on the Decrease of Water in Springs, Creeks, and Rivers" (1873).

[3] Outline of a Proposed Water Conservation and Utilization Plan, Department of Conservation, State of Minnesota, October 1932, p. 9.

An ideal and adequate conservation policy, for example, should so conform to the laws of Nature that ultimately all factors shall become so adjusted that the basic functions of the soil, water, and atmosphere cannot be impaired.[4]

The things that must be done to restore this harmonious relationship with Nature cannot be accomplished by indifferent and haphazard actions. There must be a policy and plans, and a common understanding of these. Many things must be done by individuals, others by private organizations, while some can be done effectively by governments only. The motive of self-interest must be strengthened and enriched by the motive of national welfare; and all the strength of science, education, and organization brought to bear on the problem.

1. SOME BASIC CONSIDERATIONS

WHATEVER may be attempted in the United States to make reparation for past errors by rational regulation and control of little waters, it must be recognized that there is a frame of physical laws and conditions within which the work must be done. Arrangements for the natural circulation of waters must be the base of reference in the regulation and control of little waters. It is necessary to determine what conditions must be observed strictly, from what there may be departures, and the degree of departure where it is permissible. It is desirable also to determine what things Man may do in particular localities to modify existing conditions; things that are consistent with natural laws. It may, for instance, be desirable to drain a swamp which covers fertile soils, and desirable and feasible to compensate Nature by a new man-made permanent or part-time swamp or pond on lower neighboring soils of poor quality.

The governing objective in regulation and control should be, for general rehabilitation of rural culture, all practicable conservation and profitable use of waters and soils, and revision where necessary to that end of land occupation and use. Involved in this would be component objectives:

---

[4] George Wilton Field, Biology as the Panacea for Some National Problems, *Transactions of the American Fisheries Society*, Vol. 62, (1932), p. 370.

relinquishment of submarginal and marginal cropped lands to vegetative cover and to ponds, reservoirs, and marshes; more intensive occupancy and cropping of superior lands; adoption of revised agricultural practices to eliminate erosion and promote infiltration.

The master objective should be rural rehabilitation, and control and use of little waters one means of achieving it. There would undoubtedly be conflicts that would have to be resolved. Promotion of health and sanitation might conflict in some instances with the promotion of absorption and infiltration. A reservoir, notwithstanding its many other benefits, would probably not offer healthful drinking water, unless properly treated and purified. Where there are such conflicts, *health and sanitation must be the dominating factors and must be regarded first.* Works must provide whenever feasible for live rather than dead waters. And with respect to dead waters, it should be borne in mind that if we handle them in the light of modern biology and chemistry, the malarial pond or swamp of pioneer experience need not offer an insuperable problem. The early swamp with its accumulation of rotting vegetation was one thing; modern reservoirs or ponds in which fish and fowl are abundant have biologic processes which are the enemy of mosquito-borne diseases, especially malaria and yellow fever. We shall indicate later in what a rational manner the French farmers handle this matter.

One of the basic conditions of action is that physical factors have no regard for line fences between farms or for political boundaries. The rain that falls on one farm may flow onto and erode a neighboring farm; even small streams usually traverse several townships or counties; an underground reservoir may underlie a very large area. Therefore, although detailed efforts must be those of individual farmers and small community groups, these should fit into plans and programs which are as extensive as the area of the particular definable problem.

The area of the problem of regulation and use of little waters is coextensive with the area of the United States, but any national program must consist of coordinated programs for specific small drainage areas. We may profitably calculate in terms of small headwater drainage areas. While the governing objectives are the same for all such areas, each is a problem by itself because it has its unique combination of factors. There may be an inspiring list of detailed things to be done common to all small drainage areas—this section will present such a list—but what particular combination of these things should be done in a particular area can be known only after a competent study of that area.

The program of any drainage area must be comprehensive; must take into consideration the entire area, and must include all the things to be done, each in its proper relations to the others, as required by the problem of the area. Individual programs should, where possible, be part of such a larger program. There are two principal reasons for this. The skill of soil and water specialists can be available to the individual if his is part of a larger program—specialized skill brings much more effective and economical results than the most intelligent amateur efforts—and the program of one individual or neighborhood can be interlocked with those of others, with greater individual as well as total benefit. When the main objective and the means and modes of their achievements have been determined for an area by competent specialists, each individual or community can then go ahead understandingly.

A comprehensive plan for even a small drainage area would involve numerous factors to which erosion specialists and other professional groups are accustomed to give attention. Among them are the amount and distribution of the precipitation of the area; the measured flow through its streams; the depth of the water table; the topography; the varieties of soils and to what crops each is best adapted; the areas of tilled soils and the proportions devoted to various crops; the distribution of forests, pastures, and other vegetative cover; the extent and nature of grazing by animals; the methods of cultivation; the extent of erosion and its causes. On the basis of complete information of this kind there can be laid out a plan of land use and agricultural practices for the area which tend to restore the original natural relations among the physical factors and prevent loss of water and soils. We shall later give attention to one of the notable planned developments of an entire small valley and its watershed; that of Coon Creek, "an adventure in cooperative conservation" in west-central Wisconsin under the auspices of the United States Soil Conservation Service.

However desirable it is that a program be laid out for each drainage area as a guide to the programs of small communities and individuals within the area, the responsibility of the individual is not diminished. Under any circumstance individual responsibility is present. If there is such an area program the individual must carry out that part of the plan pertaining to his own property and set an example in cooperation. If there is not an area plan there still remains the opportunity and responsibility for the individual to regulate the conditions on his own land, for his own benefit and to set an example of progressive action for his neighbors. Collective action by an entire small drainage area is often inspired more by examples of forward-looking individuals than by numerous pamphlets of information and exhortation.

There is a technical reason why the individual may and should take the initiative. The physical factors are such that theoretically the beginning of water and soil regulation and control should be at the raindrop and rill stage rather than on larger bodies of water downstream. Practically, it should be done at least simultaneously. For where there is a series of dependent influences, regulation should begin with the first of the series. Given erosion control of individual farms, conditions are set for the establishment of ponds and reservoirs on the farms; given erosion control and ponds and reservoirs on individual farms, regulation of creeks and other headwater streams by communities is more feasible; given such regulation of an entire headwater area, regulation and control of big waters below are more effective and economical. By proceeding in this manner a greater total benefit per unit of expenditure is realized.

There is an ethical reason—a reason of patriotism—why the individual landowner should take the initiative. If we would preserve our democracy of ownership of private property, then ownership must meet its responsibilities as well as enjoy its privileges. Accompanying widely distributed ownership of private property there is individual responsibility for adjusting the conditions and uses of property to social requirements. Erosion and loss of waters is not merely an individual problem; it is a social problem created by individual conduct.

In the absence of a drainage-area plan and program the individual or small community does not have to go ahead completely without skilled technical assistance. There is available the advice and assistance of agencies of the State Government and of the Federal Government. Most States have agricultural, engineering, conservation, planning, and similar technical bureaus. Immediately at hand for consultation is the county agent—probably the first one whose advice should be sought. The Federal Government has many agencies established to render just such assistance. Information and advice may be obtained from such agencies as the Geological Survey, the Bureau of Reclamation, and the National Park Service, of the Department of the Interior; the Office of Experiment Stations (and the nearest experiment station), the Bureau of Agricultural Economics, the Bureau of Agricultural Engineering, the Bureau of Biological Survey, the Bureau of Chemistry and Soils, the Forest Service, the Bureau of Plant Industry, the Bureau of Public Roads, and the Soil Conservation Service, of the Department of Agriculture; the Bureau of Fisheries of the Department of Commerce; the Bureau of Public Health Service of the Department of the Treasury; and the Federal Power Commission. Although located in Washington, many of these agencies have regional or State representatives and to all of them inquiries may be addressed by mail.

Of these, most important from the point of view of erosion control is the Soil Conservation Service. Discipline of the raindrops and the sheets of water running toward the creeks and ponds is the critical step—the point of departure. The function of this agency is to study the erosion problem, whether of a farm or of a large area, ascertain the causes, design the remedial measures to fit the circumstances, and direct, advise, and aid as plans are executed.

The advice of Soil Conservation Service is desirable because each farm is a problem by itself. Two adjacent farms are usually different as to topography, surface cover, character and combination of soils, the nature and extent of erosion, and the desirable combination of remedial measures to solve their respective problems. And although an individual landowner can safely go ahead with certain measures such as contour plowing or strip planting, which common sense tells him are essential in almost any combination of conditions, it is highly desirable that he have a lay-out map showing the places on his land where particular measures are especially desirable. The Soil Conservation Service prepares such maps for all farms included in the areas of its demonstration projects, and gives advice to all inquirers (fig. 34).

An important aspect of regulation of little waters is the necessity that measures must be economically sound; must be justified by immediate and ultimate benefits which justify immediate and ultimate costs. Broadly speaking, the cost will consist of expenditures for labor and materials of construction, labor and materials for maintenance, and the loss of other income from the land occupied by regulatory works. It should be noted with respect to the program of an individual farm that a considerable part of the cost need not consist of cash expenditures. As agronomists have been telling farmers for years, the checking of sheet erosion would involve basically only modification of farming practices. The construction of small check dams to control gully erosion could be done by the farmer himself, and most of the materials he would find conveniently at hand. The task is much like building a fence. However, cash expenditures will become a consideration where the farmer undertakes the construction of an individual reservoir, or a group the construction of a community reservoir or other similar works.

Generally, depending on circumstances in each instance, benefits will consist of elimination or reduction of capital

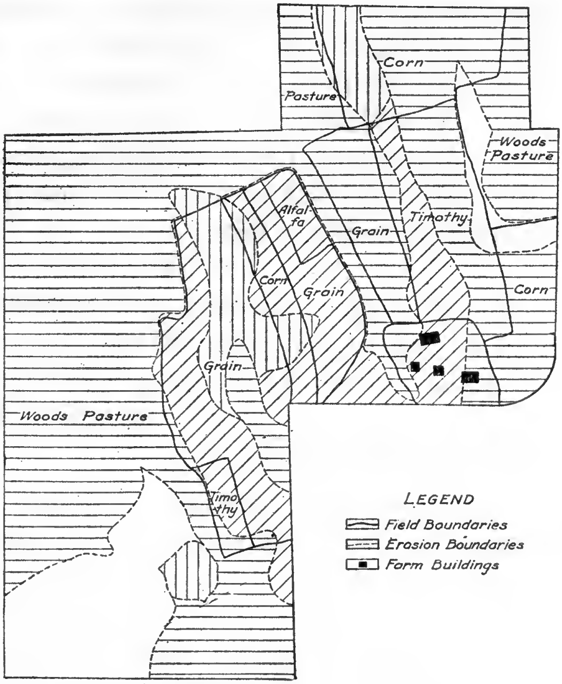


Fig. 1-A
PRECEDING LAND USE
SCALE
0 500 Ft.

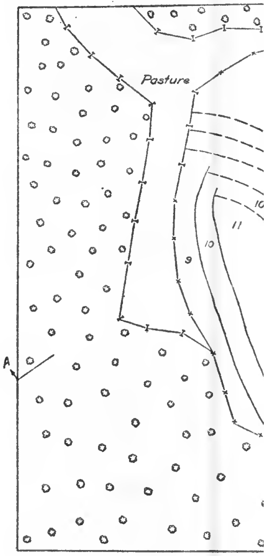


Fig. 1-B
REORGANIZED LAND US
SCALE
0 500 Ft.

EROSION LEGEND

- No apparent erosion.
- Slight sheet erosion, Less than 25 percent of the surface soil removed.
- Moderate to severe sheet erosion, 25 to 75 percent of the surface soil removed.
- Moderate to severe sheet erosion - Frequent gullies - 25 to 75 percent of the surface soil removed, and three or more gullies per acre

PLAN OF

AREA NO.	1935	1936
1	Corn	Grain
2	Grain	Clover
3	Timothy	Corn
4	Corn	Grain
5	Grain	Clover
6	Timothy	Corn
7	Corn	Grain
8	Grain	Clover
9	Soybeans	Corn
10	Corn	Grain
11	Grain	Clover

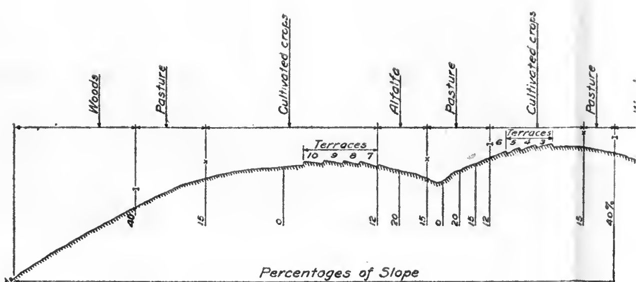


Fig. 1-C.
SECTION A-A
SCALE
HORIZONTAL — 0 500 Ft.

losses of fertile top soils, which would be a really enormous benefit; increase of the productivity of protected cultivated soils; increase of crop yields generally because of a more stable supply of underground and surface waters, and of practices incidental to land and water conservation; reservoirs for individual-farm, supplementary irrigation of valuable crops; increase of fish, wildlife, and other biological items of benefit; increased availability of fresh water for cities, villages, and agricultural communities; water for recreational purposes; hydropower; flood control; and a more substantial basis for handling the problem of pollution by sewage and industrial wastes.

Perhaps the greatest benefit would be the intangible collective benefit; the restoration of the productivity and culture of a great and important part of the people of the United States.

2. LINES OF ACTION

It should be repeated, and because of its importance can hardly be too frequently repeated, that the lines of action, whether by the individual farmer, the community, or an entire drainage area, should aim at certain fundamental things which may be summed up as an effort to reestablish, insofar as is practicable, Nature's arrangements for the natural circulation of waters. These fundamental things are:

First, the promotion of absorption and infiltration at the raindrop, trickle, and rill stage, by maintenance of a reasonable proportion of vegetative cover; by wise rotation of crops and proper methods of plowing, cultivating, and other treatment on lands generally tilled and grazed; and by making waters "walk, not run", at the stage of creeks and other small streams by means of check dams and similar devices.

Promotion of infiltration is the basis of constructive action; first, because measures that promote infiltration at the same time help to prevent erosion, and second, because ground storage is our most important source of water supply.

So far as the fruitfulness of the land is concerned, the essential stage in the natural circulation of water is that of the temporary lodgment in the soil and subsoil and adjacent rocks, for it is during this stage that the water is available for the needs of plant and animal life.[5]

Second, for utilization of waters that now go to waste in large volume, the establishment of ponds and backwaters on individual farms, and the establishment of lakes and larger backwaters—sometimes even the restoration of marshes and swamps—by communities on the larger headwater streams by means of check dams and in some instances small masonry dams. Such retardation of the flow of waters to the large rivers will have beneficial results, in some instances building up the ground water and thereby affording a better well supply; in others offering means of individual-farm and community supplementary irrigation, and clear streams for additional water supply and for fish, wild fowl, and recreation. On the larger tributaries below the headwaters, flood crests may be reduced and a better flow maintained throughout the months of moderate or no rainfall.

[*a*] THE INDIVIDUAL FARM

The waters on the individual farms come mainly as rain and snow, and they proceed oceanward in the form of rills, rivulets, creeks, and rivers. Aside from the part absorbed by the soil, varying amounts are intercepted and retained, at least temporarily, in marshes, bogs, swamps, lakes, ponds, the sites of former ponds, and in natural depressions. Wise handling of waters, and of land in relation thereto, in connection with the primary forms of water on land, can solve most of the erosion problems and contribute much to obtaining new benefits from waters that now flow rapidly and wastefully to the seas. As George W. Field has observed, "Dirt farming must now be coordinated with water farming to provide a balanced food ration for a well-balanced nation."[6] Balancing the biological budget helps to balance the financial budget.

---

[5] W. J. McGee, Wells and Subsoil Water, *Bulletin No. 92*, Bureau of Soils, U. S. Department of Agriculture, p. 8.

[6] Hearing before the Committee on Agriculture, House of Representatives, 71st Cong., 3d Sess., Feb. 6 and 13, 1931, to Conserve Run-off or Flood Waters, Consideration of Wildlife Conservation, p. 34.

[1] *Selective Use of Land.*

The primary step at this stage is determination of the uses to which the different parts of a farm shall be put, depending on topography, the character of the soils, and in some degree, market conditions and facilities. Only the more fertile and level lands should be devoted to tilled crops. Generally, climate and soils permitting, lands of excessive slope should be given over to forests and permanent pastures, as also should the poor soils; and where these conditions are in combination, forestation is certainly in order. In many agricultural sections of the United States are remnant woodlots. These should be conserved as potential permanently productive lands, which they are when properly handled and guarded from grazing, fire, and other disturbance such as the rooting of hogs. If permitted, they will establish seedlings and increase. These seedlings, and others procured from State nurseries, of which one purpose is to make low-cost seedlings available, can be used to plant other hilly or poor soil areas. On some favorable sites other than natural woodlots, planting may be made—such as nuts, honey-locust, persimmon, briars, fruits. These measures may require patient waiting before steady income is realized, but in the meantime a permanent asset is being developed.

In most sections of the country where trees are not native, grasses thrive. In such areas particularly, but also in areas where trees will grow, some parts of the land should be assigned to permanent sod cover, and in other parts such cover given a definite place in the rotation of crops. Some sod cover may be for pasture and other, such as alfalfa, for the intensive production of high-protein feeds. In the long run some soil profiles may be so changed by vegetation, in both the surface and subsoil layers, as to increase materially the infiltration capacity.

At one stroke, by such a selective use of land an effective gesture has been made to Nature; the restoration of a potent natural device for retardation of run-off and promotion of infiltration, that is, the reestablishment of mechanical retarding agents, humus, and a root zone for easy infiltration.

Sometimes promptly and generally in the long run profit will replace loss for those who adopt practices which follow the principle that crops should be adapted to the natural characteristics of the land. The cards are stacked against those who attempt to modify the land to fit a particular crop.

[2] *Rotation of Crops.*

Those lands which are set aside primarily for cultivation—any degree of which is a violation, necessary to maintain a high standard of living, of Nature's original arrangements—should not be employed too exclusively for the production of a single crop. This principle is now expressed in the best farming practice. Uninterrupted cultivation promotes erosion and loss of the top soil is a drain on the farmer's capital assets. As has been explained in some detail, soils utilized under a system of continuous single crops, especially clean-tilled crops such as corn, cotton, and tobacco, lose much more soil and moisture than do soils devoted to crop rotation. For the purpose of soil and moisture conservation, therefore, as well as for replenishment of the humus supply and added fertility through the growing of legumes, the economy of each farm should be so designed as to permit the rotation of crops on the largest possible part of the area generally devoted to cultivation. By crop rotation another step is taken toward conformity to Nature's basic requirements.

Forces generated by the World War appear to have so changed economic conditions that a new agricultural economy must be developed in the United States. In that connection there will be required wise judgment and skillful management of agricultural factors—conservation as well as exploitation; conservation of water assets as well as soil assets.

On any basis of calculation the time is past when farm management without judgment and skill can succeed. Overdevelopment of single-crop agriculture under conditions of large export which is not likely to be regained for many years has so increased production relative to demand as to prevent in all probability a return to former profitable price levels in the instance of some of the major crops produced under the single-crop type of farming. Referring to the Big Creek erosion project of the Soil Conservation Service in north-central Missouri, where the corn acreage reduction amounts to 37 percent for a 5-year period on the cooperating farms, it has been said, "This (reduction of single-crop acreage) obviously implies a long series of economic readjustments within the individual farm as well as in its outside relationships."[7] These changed conditions mean that the farmer must apportion his soil assets among more lines of production in combinations varying according to climatic and soil conditions and the demand-supply trends in agricultural markets.

[3] *Cultivation of Tilled Lands.*

The problem of conserving water supplies and preventing erosion will be solved in part by a rational assignment of land to forest cover and sods. But the most difficult part of the problem still remains, that of proper treatment of the cultivated areas. The forest, sod and aquatic treatment is entirely in conformity with Nature's procedure. The cultivation of land is in opposition to that procedure. However, civilization is built on the production of cultivated crops. The problem resolves itself into one of securing the benefits of cultivation in a manner which departs least from natural arrangements. There are several practices which in combination go a long way toward meeting these conditions.

First; there is cultivation itself. Frequent, but not too frequent, cultivation where the nature of the crop makes it possible is highly effective in conserving soil moisture in that weeds are destroyed and transpiration thereby reduced to a minimum. Where effective weed control can be obtained without excessive pulverization of the soil, some gain with respect to increased absorption of rainfall results. That is to say, a granular or fine-fragmental condition of the soil is not only more favorable to absorption of water on most temperate zone soils as compared with a dust-fine condition, but the rougher surface of the coarser soil offers somewhat

[7] R. Schickele, J. P. Himmel, and R. M. Hurd, Economic Phases of Erosion Control in Southern Iowa and Northern Missouri, *Iowa Agricultural Experiment Station Bulletin No. 333*, p. 194, June 1935.

greater resistance to rate of run-off and therefore to erosion. Deep preparatory tillage—subsoiling—is especially favorable to increased absorption and retention of rains and melting snow on soils having hardpanlike subsoil (but not with sticky clay subsoils such as run together and become again impervious with the first saturating rains).

Second; contour plowing—at right angle to the slope—is an important part of the best farm practice. Because of the custom, particularly in the Middle Western States, of laying out counties, townships, highways, sections, and fractions of sections on rectangular lines, there has developed the custom of fencing fields on similar rectangular lines and of plowing parallel to the fencing. (It is of interest to note that generally in Europe the boundaries of properties and fields follow contours.) This causes many furrows to extend down slope, thereby making them channels which hasten run-off. The wise practice is to plow with the contour, rather than up and down the slope, so that furrows are at all places at right angle to the direction of flow of surface water and thereby serve as obstacles to run-off. This promotes retardation and infiltration and causes sheets of water to drop any soil they are washing off at the points where they strike ridges formed by the furrows.

Third; where cultivation is on moderately sloping land, terracing is helpful. We do not have in mind the laborious terracing of the walled type found in countries where fertile land is scarce and every square foot, even on mountain sides, must be cultivated, as in the vine country along the Rhine; what we have in mind is simpler but nevertheless helpful. There are various kinds of terracing (Mangum, now most favored, Nichol's, Duley's, and Onley's) between which it is not practicable to distinguish here, but the common characteristic is the creation by grading up of approximately parallel ridgelike strips of soil, generally variable as to grade, but of a grade considerably less than that of the slope across which the terraces are constructed. The greatest change in level is concentrated in the shoulders, which may be strip-planted. The water channel above the terrace ridge must not have a grade steep enough to cause excessive scouring. In humid regions the grade usually should not exceed one-half of 1 percent, or 6 inches in a linear distance of 100 feet. The principal function of these cross-slope ridges is to intercept water flowing downhill and to carry it off to the sides of fields at a gentle, nonerosive rate of flow. In regions of low rainfall, level terraces are frequently effective for catching a large share of the rainwater and sinking it into the soil. Aided by contour plowing and strip-planting (discussed below), terraces are even more effective in retarding the run-off and promoting infiltration.

Fourth; strip-planting, usually referred to as strip-cropping, should be more generally practiced. Across the slopes, after the manner of terracing, strips of thick, water-conserving, soil-holding crops are sown in approximately parallel bands of varying width, usually following the contours. Sandwiched in between these bands are strips of the cultivated crops, such as are not favorable to effective infiltration of water or to retardation of flowing water. These contour bands may be planted, in the case of permanent strips, to fruit trees or berry bushes; and in the case of rotation crops, to sorghum, grass, or other dense crops. Strip-cropping is especially suitable to localities where hay is a marketable commodity or where considerable livestock is kept. Ordinary strip-cropping is usually practiced in the form of a system of crop rotation, since the parallel bands usually are arranged so that the alternating strips are planted in the following order: one strip to a dense, soil-saving crop, and the next to a cultivated or erosive crop.

Contour plowing, efficient cultivation during the growing season, and such terracing and strip-planting as are reasonably practicable, go a long way toward compensating Nature for treating soils as was never intended should be done—compensation for the removal of the vegetative cover and disruption of the normal soil firmness (or stability) by farm tools. Were these practices universal, there should be no great fear of erosion where excessively steep, highly erosive slopes are not used for the cultivated crops. Also these practices, together with the influences of restored forest and sod cover, should remove fear, generally, of dangerous depletion of the groundwater supply, and of the drying up of creeks, small rivers, and lakes.

The reader may be inclined to think that this is too expensive a form of agriculture. From the point of view of an era when there was plenty of free or moderately-priced fertile land, when an owner could exploit one particular farm and then move to new and fertile land previously untouched—what the Europeans long ago named "robber agriculture"—from that point of view it may usually be a more expensive form of agriculture to the individual, although not to society. However, that era of exploitation is passed. Today the landowner who desires to leave to his children a farm that is more productive—worth more instead of much less—or a nation that desires to maintain self-sufficiency in feeding, clothing and housing itself, must observe those agricultural practices which will conserve the waters and the soils. It is no longer possible to abandon "robbed" land and turn to new, rich lands to be had at the cost of a trek in a covered wagon. As a matter of fact, numerous farms can be operated much more profitably on a basis of correct land use, such as that called for under the system of soil and water conservation outlined above, than where all the land is farmed without regard to principles of soil adaptability and soil conservation.

On many farms conservation of water and soil would be a relatively simple matter—would involve chiefly contour plowing and crop rotation, and perhaps a moderate amount of strip-cropping. So urgent is the problem that McGee said years ago that the individual landowner should be made responsible:

> both for the public welfare and for the benefit of the owner, each farm should be made to take care of all the water falling on it during the entire year; and all that part of the water not needed for immediate crop growth or cistern or other supply should be so caught and absorbed by mulch or well-tilled soil or contour furrows and ridges as to pass into the ground, there to be stored against need for the steady supply of streams through seepage and for the gradual restoration of the sadly depleted reservoirs of subsoil water.[8]

[8] W. J. McGee, Wells and Subsoil Water. U. S. Department of Agriculture, Bureau of Soils, *Bulletin No. 92*, Mar. 26, 1913, p. 184.

U. S. SOIL CONSERVATION SERVICE

Figure 35.—Contour plowing and terracing conserve soil and water.

U. S. SOIL CONSERVATION SERVICE

Figure 36.—A terrace holds back water for absorption and infiltration after a rain.

Figure 37.—Strip cropping increases the stability of contour-plowed land.

U. S. SOIL CONSERVATION SERVICE

U. S. SOIL CONSERVATION SERVICE

Figure 38.—Series of small check dams in a shallow gully.

Figure 39.—Check dams hold back water for absorption and infiltration and save the soil.

U. S. SOIL CONSERVATION SERVICE

Figure 40.—A sturdy check dam is necessary for a deep gully.

U. S. SOIL CONSERVATION SERVICE

U. S. BUREAU OF AGRICULTURAL ENGINEERING

Figure 41.—Check dams along highways help to conserve and control water.

Obviously, this recommendation contains impracticable suggestions; it is cited to indicate how serious a pioneer investigator considered the problem of water conservation.

[4] *Check Dams in Gullies.*

The improved farm practices noted above pertain particularly to sheet and rill erosion, its earliest stage. But on many farms in the United States erosion has reached the much more serious stage of gullies, large as well as small. There is much the individual landowner can do to check gullying, and in some favorable places even restore gullied land to a state suitable for cultivation. In rare instances terracing will restore moderately gullied land, but generally it is necessary to construct at the head and at more or less short intervals in a gully (depending on its characteristics), check or stabilization dams which consist of a small line of posts across the gully against which are laid logs, brush, rocks, straw, woven wire, metal waste, and other materials. Where gullying is very bad, dry stone wall checks may have to be constructed. However, in contrast, one of the outstanding recent achievements of the Soil Conservation Service is the development, particularly in the Piedmont section of the United States, of a unique low-cost method of gully control requiring only labor and vegetative materials—logs, brush, straw. The effect of these methods is to reduce the velocity of the run-off and thereby its carrying and cutting power. There are many instances in which reduction of velocity has caused the dropping of soil in suspension to such an extent that it has in a very brief period filled up a gully of considerable size to a level with the surrounding land and restored the site to cultivation. In other instances, especially on steep slopes, the check dams stabilize the situation until planted shrubs and trees can get a hold, and eventually a permanent brush cover or even a new, productive forest is created.

[5] *Check Dams on Streams.*

On many farms are creeks or other small streams which once carried water throughout the year, but today serve only as channels to hurry rainy-season run-off to the lakes and rivers and in the summer run dry. In the season of heaviest rainfall or melting of snows these streams, as well as those which are naturally intermittent, are eroding agents which gradually gnaw at their banks until these cave in, thereby reducing the area of cultivable soil. If these creeks are treated by check dams, wing dams, and baffle dams at short intervals, obstructing works such as are made by windfalls and by beavers, logs and brush and straw lodged against a crossing line of wire fence, flow is retarded and infiltration promoted. In some instances backwaters and pools that will last for a considerable period and be an attraction to wild and domestic fowl, will be established. This practice is of course not applicable to torrential streams. The latter require more substantial works of stone or concrete.

If such check-damming is part of a comprehensive scheme of new farm practice, including restoration of forest and sod cover, contour plowing, terracing and strip-cropping, and especially if such comprehensive practices become general throughout a community, a beginning is made of restoration of some of these streams to something like the year-round continuity of flow which existed before Man broke the balance of natural arrangements. Continuity of small stream flow makes possible the maintenance of backwaters and pools which can be put to uses to be noted later. At this point in the circulation of waters there is added through Man's efforts a series of profitable uses of surface waters which now are wasted.

[6] *Ponds and Reservoirs.*

Where circumstances permit, and in some sections of the country circumstances are favorable on a considerable proportion of the farms, individual farm reservoirs may be constructed. These may require in some instances engineering counsel and designing, the provision of spillways and other devices to prevent dams being washed out in flood-flow season, although our nonprofessional, resourceful forefathers built many a substantial dam. There is no good reason why the profession of engineering should not lend its resources to the promotion of such small works. An almost exclusive interest in big works should be expanded to include interest in small works, no matter how small, that promise individual and social benefit.

Reservoirs would be of various kinds. Some of them, perhaps most of them, would not be expected to hold water throughout the year and would serve primarily to promote infiltration and increase the supply of ground water. Others would be expected to hold water and at the same time permit some infiltration, for even though a dam is designed to retain the water there is some inevitable seepage. F. H. Olmstead, an engineer of distinction in this field, once testified that he had—

> observed many times in his practice in building mountain retardation structures that the zone of moisture under the influence of these small heads has been wonderfully enlarged over the original conditions.[9]

But primarily these reservoirs would provide water for various important farm uses, especially in times of drought. They would provide fresh water for domestic animals; they could be stocked with fish for food; they would benefit and attract wild fowl. Through proper provision for gravity flow, or pumping if necessary where cheap electric power is available, an abundance of water would become available for the household—which means the advantages of flowing water in the kitchen and in bathrooms—for the barns, and for fire protection. For the more intensive higher-priced crops—garden stuff, potatoes, and other crops that can carry the additional cost—water would be available for supplementary irrigation. Generally, however, such water would not be suitable for drinking.

Although the term reservoir suggests formal engineering works, it should not be inferred that they in all instances require such works. Impounding of waters may result, as in India, from—

> blocking the line of a stream or closing the outlet of a natural depression in which rain collects; in places it may take the form of a hollow in the ground fed by a channel cut from a neighboring stream. Sometimes a series of dams are placed across a valley so as to give a chain of tanks, the surplus from the higher feeding the lower.[10]

---

[9] S. Doc. No. 436, 65th Cong., 3d Sess., p. 29.

[10] A. V. Williamson, Indigenous Irrigation Works in Peninsular India, *Geographic Review*, Vol. XXI, No. 4, October 1931, p. 614.

And of course a supply of water for supplementary irrigation may be obtained by pumping from the ground, especially where electric energy is cheap.

With low-cost electric energy available for pumping, a matter considered in more detail later, there would be under proper conditions opportunity for the use of the same water several times before it would escape to the rivers. Pumped from the groundwater store and applied to supplementary irrigation, such part of the water as is not evaporated and transpired would infiltrate back into the groundwater reservoir and become available for reuse. If extensive use of pumped water existed over large areas, even some of that which is evaporated and transpired might be returned somewhere in the form of rain.

The value of supplementary irrigation, especially applications of water at critical periods of the growing season, *even in climates where the average annual rainfall is adequate*, is not yet fully appreciated. The stage of experiment has been passed, and the following has been adequately demonstrated. The annual rainfall may be adequate, but not distributed with regularity from year to year or throughout any year. Availability of water permits calculated regularity of application. Also each crop has a critical period of growth when, if enough water is available, the yield will be much greater than it would be otherwise, even if an equivalent amount of water were available earlier or later. Sometimes rain provides sufficient water during the critical period, but frequently does not; and often, if adequate at the critical period of one crop it may not be for the critical period of another. But if a farmer has a small individual reservoir or other impounded water, or wells, and cheap energy for pumping, he can be more certain that each crop will receive the proper amount of water during its critical period and at other times if Nature fails. In addition, within limits, every application of water will increase yield, the rate of increase and the limit varying with different crops. Supplementary irrigation is a form of crop insurance.

We are accustomed to think of irrigation as important only in the arid western areas, for there it is absolutely necessary. But irrigation to supplement generally adequate rainfall is being developed in the humid eastern part of the country. Its benefits in the production of vegetable crops, even where the total annual precipitation is ample, may be summarized as follows:

(*a*) To tide over periods of drought which might otherwise materially reduce or wipe out the yield.

(*b*) To make it possible, through control of moisture conditions throughout the growing season, to produce a larger yield.

(*c*) To secure a better quality of crop by making possible continuous growth, which is essential to high quality.

(*d*) To make it possible to apply water at critical periods of growth.

(*e*) To obtain a good start for plants transplanted into a dry soil.

(*f*) To obtain prompt germination of seed at the time of sowing, especially important in the case of a succession of crops.

(*g*) To make possible the preparation of soil which without irrigation would be too dry for plowing or pulverizing.

(*h*) To protect especially vulnerable and valuable crops from light frosts by overhead irrigation.

[7] *Swamps, Marshes, and Wet Lands.*

While designed and regulated restoration of the different classes of wet land as a social asset is undoubtedly, because of the scale on which it usually must be done, a responsibility of organized communities, especially the States and the Federal Government, there are many farms on which the owners might advantageously make the beginnings of such restorations. On many farms are considerable areas which were once marsh or wet but have been drained dry. While in the greater number of instances fertile, tillable soils have been uncovered, in some other instances the soil has proved to be unsuitable for cropping, even for the preferred forage crops and grasses, and the condition of dryness is unsuitable for the return of the original marsh hays, huckleberries and other natural cover. The stoppage of the drainage outlets of many of these plots would lead to restoration of their natural wetness and encourage the spontaneous reestablishment of the grasses and other cover which they would then favor.[11] Marsh hays have some value for pasturage and for

[11] For the dominating importance of health considerations see p. 44.

cutting; blackberries, cranberries and other shrubs bearing edible fruits could be replanted and be made a source of income where the climate and soil conditions are such as to constitute their respective native habitats. Such cover would also attract birds, rabbits, and other wildlife, which could be made a source of income. Incidentally, here and there infiltration and maintenance of the groundwater supply would be promoted, and these plots would stand ready to be incorporated into a community plan of zoning and reestablishment of extensive swamp, marsh and wet lands, a matter to be considered later in this report.

It is not the thought that every owner could or should do all of the things that have been suggested, for conditions vary. But certainly everyone can plan for the long run, which involves conservation insofar as possible of his principal assets—land and water. Everyone can and should make a judicious selective use of the various parts of his land. Everyone can and should cultivate his tilled lands in the manner which conserves his assets—by crop rotation, contour plowing, efficient cultivation, and some practicable degree of terracing and strip-planting. Supplementary to these he can by check dams and similar retarding devices control gullies where they have appeared, for these represent an advanced form of loss of his principal asset. In addition to such control measures each landowner should explore seriously the extent to which he can check-dam creeks and other small streams, and establish for himself a reservoir for the numerous benefits which have been enumerated. Every farm is a problem by itself, and measures for the conservation and proper utilization of the soil and water must be undertaken in terms of its combination of conditions.

[*b*] THE SMALL COMMUNITY

On the principle that, speaking broadly, problems must be solved by beginning to make corrections at the remotest points of origin, the problems of water conservation and soil erosion control should first be solved on the lands of individual owners, as has been discussed above. The next logical step is removal of unfavorable or promotion of more favorable community conditions. Community action can on the one hand accomplish certain things that cannot be undertaken by the individual landowner—some things are done best and most economically by cooperation—and on the other hand they can stimulate, encourage, and reenforce the undertakings of individuals. This may be particularly the case where an agricultural community centers on a rural hamlet.

In a rural community of progressive characteristics, or in a community among whose members are two or three leaders possessing manifest qualities of leadership, much may be accomplished; especially where the leadership is such as to have the vision, understanding, and energy to enlist on behalf of the community the ready services of county agents, and through them of specialists from experiment stations, agricultural colleges, and the various agencies of government.

The opportunity of organized community effort is, on the one hand, to bring friendly pressure to bear on individual landowners to do all that is practicable on their respective properties, and on the other hand, to undertake measures that lie beyond the capacity of the individual. Perhaps for the small community the biggest opportunity lies in the regulation and control of the larger creeks or small rivers which may form the boundaries between different ownerships, or if concerned with a single ownership, have potential uses which would be of benefit to a community and require new uses of land or works, as for a reservoir, beyond the capacity and interest of an individual to undertake.

In respect to these larger creeks and small rivers the first consideration of the community should be the construction of numerous check dams which will retard stream flow, create backwaters, and in general promote infiltration. These check dams may be of the same nature and size as those on the smaller creeks of individual farms, but some of them would be larger. They may be constructed by felling interlocking trees, the dumping of large boulders, and the building of a line of posts across streams, the plugging of openings by hay, cornstalks, straw, and other materials. If properly spaced the force of a stream will be broken even in time of flood, and they should last for a considerable period. Such simple barriers, made by windfalls and by beavers, were common in the early period of settlement and were durable. In some instances baffle dams and wing dams more formally constructed of staggered sections of fence, reinforced by rocks, logs, staves, wire, hay, and straw, may be desirable; they leave openings for the stream flow, yet retard the flow and maintain pools. Where the terrain is rugged and streams more torrential, substantial check dams of rock and concrete are necessary. The kinds of retarding devices suitable for a particular stream can be determined by specialists of the neighboring experiment station.

In some communities the lay of the land and the streams may be such that the community may undertake as a collective enterprise the construction of a masonry dam and the creation of a relatively permanent reservoir which would impound water for various community uses. Such dams should be constructed only in accordance with the designs and under the supervision of a competent engineer.

The benefits of such reservoirs may be of several kinds, one benefit being dominant in one community, some other in another community. In all instances they should provide an abundant supply of fish, the waters being clear because of control measures on feeder streams from individual farms. They should offer local recreational facilities. A natural picnic ground with water is a distinct community asset. Families will drive many miles to find such a site. Such waters should attract some wild fowl and other game. They could be used to improve the fire protection and sanitation of hamlets. More closely related to the productive activities of communities, they may with favorable conditions of topography provide water for supplementary irrigation of the crops of the community.

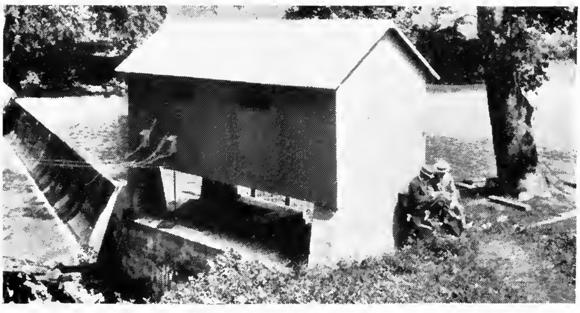
The extension of cheap electric power into the rural community would provide flexible pumping facilities, and the irrigation requirements would create a market for the power. In some instances the impounded water might become a source of electric energy on a small scale, not only for farm pumping but also for small community industries—natural

U. S. SOIL CONSERVATION SERVICE

Figure 42.—Small Missouri individual-farm reservoir with earth dam.

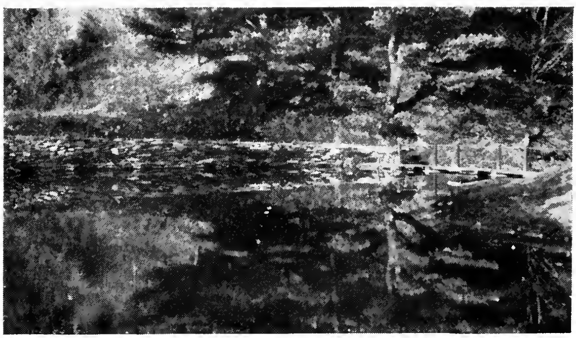
U. S. AGRICULTURAL EXTENSION SERVICE

Figure 43.—Jointly owned, inexpensive rural reservoir in Tennessee.



U. S. BUREAU OF AGRICULTURAL ENGINEERING

Figure 44.—Mutually owned, small reservoir and power plant—concrete dam.

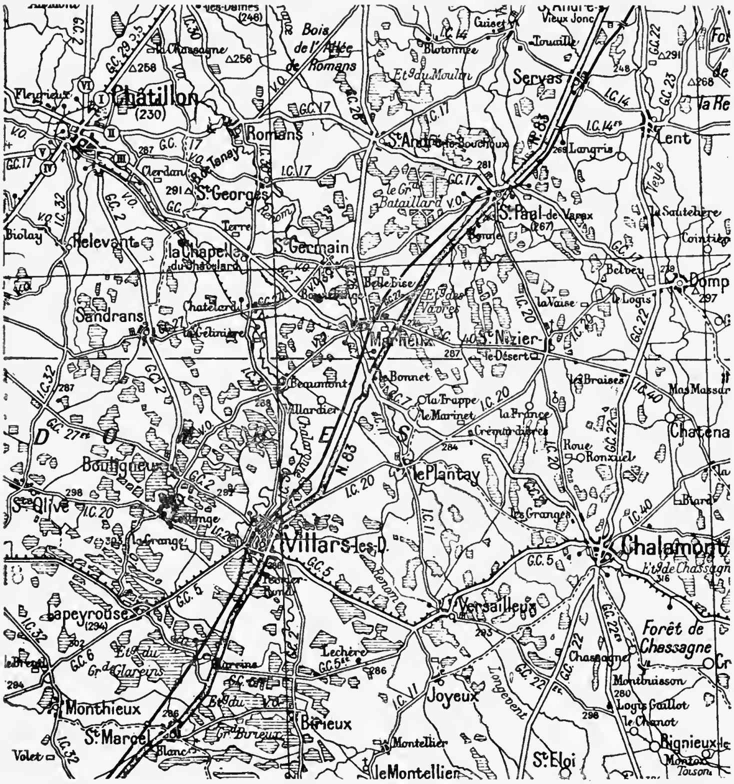


U. S. NATIONAL PARK SERVICE

Figure 45.—Small recreational reservoir in a New York State park.

Figure 47.—A Rhone Valley temporary reservoir on the site of a grain field—"water farming" in rotation with "land farming."

DR. GEORGE W. FIELD



DR. GEORGE W. FIELD

Figure 46.—Map of small sector of the upper Rhone Valley (France) showing numerous farm reservoirs.

Figure 48.—A Rhone Valley grain field on the site of a drained reservoir—"land farming" in rotation with "water farming."

DR. GEORGE W. FIELD

community industries based on the raw materials of the community, such as gristmilling, woodworking, weaving, and canning. Of course, small hydropower sources of the kind under consideration are not dependable as to the constancy of the volume of water supply, the head of water and the energy generated; and under present conditions the kilowatt cost might be too high. These things would have to be taken into consideration in any planning. But the time is apparently not distant when all sources of electric energy in an area will be hooked together by high-tension transmission lines into great circuits or pools of power—into "grids" as the technicians call them—and when that is the case, even small and irregular power sources may be hooked into a system on a variable give-and-take basis, and with new conditions of cost, to the advantage both of the entire system and of the individual consuming centers. Of greatest importance for rural development, however, is not the energy which small power sites could contribute to the interconnected system, but the low-cost energy which the system could offer to the rural communities.

In a few instances also a community may by cooperative arrangements undertake a land-selection development wherein is arranged restoration of swamps, marshes, and other natural wet lands of poor soils, reforestation on uplands, and pasturing on intermediate slopes; undertakings for the purpose primarily of promoting infiltration, building up the groundwater supply, increasing the seepage into the now regulated small streams, and eliminating erosion. But on the whole, undertakings of land selection and allocation to use on an extensive scale are a responsibility of authorities of larger areas under general permissive legislation; which is fortunate, for such community undertakings should be in accord with plans for larger areas.

At this point, as an example both of individual farm management and of community cooperation, certain European practices may be of interest. We cite the Upper Rhone Valley in France as an example.[12] Its characteristics are in

[12] From unpublished notes by Dr. George W. Field, consulting biologist.

major respects similar to those of the Upper Mississippi Valley—hills and stretches of moderate gradient; fertile soils intermixed with rocks, pebbles, gravel, sand, and clay; and streams winding among the hills and over the gently sloping areas.

French farming is noted for its efficiency. It is based on the principle of working with Nature; of adapting the crops to the land, rather than attempting to adapt the land to crops, and of utilization of all factors of soil and water—physical, chemical, and biological. With respect to some of these factors neighboring farmers cooperate, as in the use of waters. As is indicated in figure 46, the Upper Rhone Valley is dotted with ponds, most of them man-made. The location of these ponds is shifted from year to year, in accordance with each farmer's rotation of "land farming" with "water farming", based on cooperative arrangements respecting the use of waters.

These temporary ponds may vary from a few acres to six or seven hundred acres. The most satisfactory location is a slightly depressed, typical grain field. This area can if necessary be surrounded by an earth dike to insure the size and depth needed to capture and retain the usual run-off. The depth, which varies with the danger from ice, the local rate of evaporation, and with the amount of rainfall or stream water which may be expected to replace the evaporation, is usually not less than 4 feet.

The rotation of use of such a site, variable to meet market and other conditions, is generally as follows: 1 or 2 years of water crop (fish and fowl) alternating with 1 year of grain (wheat or barley). Each crop prepares and improves the soil for the next. This treatment may in places and on occasion be supplemented by small quantities of lime and potash (wood ashes) or phosphate (rock or acid) and nitrates (protein waste from house and barn) to correct accidental deficiencies.

The biological principle involved is that the stubble of grain, the cellulose material and dead leaves and twigs when under water are attacked and eaten by fungi, notably bacteria. Floating in the atmosphere and resting in the soil and other materials are dried bodies of plants mingled with which are forms of animal life—infusoria. These and similar organisms become activated in the presence of water, if it is correct in quantity and quality. The end result is aquatic vegetation that is food for fish and fowl, the farmer's water crop. After the pond is drained in the rotation plan, the aquatic vegetation is greedily pastured by the farm animals, while the protein material left behind, including the unutilized bodies of fishes and aquatic animals, becomes transformed into manure for the following grain crop. Because of the regulated biological action incident to the rotation, these ponds are generally free from malaria.

Under favorable natural conditions generally, equal areas yield comparable profits from both land and water farming, and thus are reduced the natural hazards in farm practice.

[*c*] SMALL DRAINAGE AREAS.

As an illustration of what may be undertaken for erosion control and water conservation on the scale of an entire small valley, the "adventure in cooperative conservation" of Coon Creek Valley, in west-central Wisconsin near La Crosse, is illuminating. One of the first demonstration areas of the United States Soil Erosion Service, now the Soil Conservation Service, was the Coon Creek Project.[13]

The Coon Valley is one of the innumerable little headwater units which make up the great Mississippi River system. A valley of scenic hills, excellent soils and rich grasses in the clearings, its major agricultural contribution to the national income has been, at first wheat, but more recently principally butterfat and tobacco.

When settlement and the development of its agriculture began about 1850 everything was all right because there were more hills and trees and sods than farms and animals. There was a rich cover of humus, built up through centuries; the streams ran clear, deep, narrow and full, and were filled with trout; the streams seldom overflowed (the first known flood was in 1873), and the early settlers often stacked their

[13] This section generally an adaptation of Aldo Leopold's Coon Valley, in *American Forests*, May 1935.

hay on the creek banks. The deep loam of the steepest fields took the rain as it came, turned it upward into crops and downward into perennial springs, and gullies were absent.

Then came increase in settlement—thrifty, ambitious Norse farmers—more cows, the need of more silos to feed them, and of more machines to milk them. This development required more pastures for grazing, on which account forest land was cleared on the steeper upper slopes; and more tilled land for ensilage corn (and eventually for tobacco), for which sod lands on the lower levels were turned under. All of this exposed the fertile topsoils to the rains pouring off the ridges as from a roof, down ravines crossing grazed slopes as through gutters, and in sheets off the more level tilled fields. They could not resist the abrasive force of these silt-laden waters, and in time great gutters were torn in the hillsides, and the humified soil was in many places washed into the streams.

The Coon Creek erosion project is an attempt to combat these evils at their source and to restore insofar as possible the earlier conditions. Some 315 farmers, approximately half of all the farmers in the watershed, have entered into a program of cooperative rehabilitation. The Soil Conservation Service has made contracts with the farmers, which collectively comprise a regional plan relating to land use and cropping, and methods of farm practice; and has developed a system of check dams in gullies and planting along streams; furnished free labor, wire, seed, lime, and planting stock; has established a nursery, seed warehouse, lime quarry, and other facilities; a C. C. C. camp for necessary labor; and especially a staff of skilled technicians for studies of the whole problem and the problem of each farm, the making of plans and designs, and supervision of their execution. The farmers contribute cooperation—adoption of recommendations for development of their respective lands, and assistance in execution.

The project is developing essentially as follows: Cows and crops are to be kept from the steep slopes and these are to be henceforth devoted to timber and wildlife. The withdrawal of these lands from cultivated crops is to be compensated by more intensive cultivation of the flat lands. Gently sloping fields are to be terraced or strip cropped. These changes, plus contour plowing, crop rotation, and the repair of eroding gullies and stream banks, constitute the essential features of the restoration movement. It is interesting to note that the plans include the planting in odd spots of sorghum, millet, sunflowers and so on, as feed for wildlife. (Fig. 34.)

In the Coon Valley of Wisconsin is found one of the demonstrations of how an entire small drainage area may, under the leadership and supervision of a bureau of the Federal Government, plan and carry through the rehabilitation of its unwittingly abused lands—the restoration of diminishing individual and community assets. The Soil Conservation Service is at present carrying on 130 similar soil conservation demonstration projects in eroding areas throughout the United States; and in addition smaller demonstrations maintained by C. C. C. labor. This leadership of the appropriate agency of the Federal Government is necessary for the planning, and for effective organization and execution. But there must be among the landowners themselves in each locality, leaders who see the problem and can bring the ready assistance of the Federal bureaus to focus on it, and all landowners of the area must contribute support to their constructive leaders and cooperative effort to the assisting Federal agency.

[*d*] COUNTY, STATE, AND FEDERAL GOVERNMENTS.

This report is concerned with headwater streams and other little waters; not with major tributaries, large rivers, and other great waters. Navigation, flood control, major hydropower, regional irrigation and reclamation, and other great land and water regulation problems are already the concern of the Federal Government and of cooperating States. The Federal Government, the States, and counties should recognize also responsibility and opportunity in the problems presented by little waters. Many of the problems which appear on the larger streams, such as extremes of flood crests, extremes of low-water flow, and siltation of reservoirs, are complicated and increased by neglect of regulation and control of headwaters and even of run-off on tilled and grazed lands. And more important to governments than the influence of little waters on big waters, is their responsibility for the general welfare; for—because governments can do things that individuals and small communities cannot do—elimination of erosion and increase in the use of waters now going to waste.

Governments have an inescapable responsibility for the conservation and wise use of all natural resources, especially soil and water. Owners have actually merely a lifetime interest in their lands; but communities, counties, States, and the Federal Government have a perpetual interest in the preservation of this indispensable asset.

While undoubtedly there are some undertakings in respect to headwater streams, small rivers, and lakes in which governments should engage directly, the principal opportunities of a State are: First, educational work through agricultural colleges and other technical schools, much of it in cooperation with the Federal Government; second, planning the selective land-use development of entire intrastate watersheds; third, financial contributions with attached conditions which will bring about standardization of the best methods and coordination of the efforts of independent communities and authorities; and fourth—a matter of great importance—permissive and directive legislation which creates a favorable environment for the organization and operation of voluntary and incorporated associations of the citizens of lesser areas. Statutes governing the organization of drainage districts are illustrative of such legislation, although these particular statutes are not completely to the point, for their influence has been to promote excessive rushing of waters to the big streams.

What is now needed is similar permissive and directive legislation for the creation of conservancy districts and authorities much simpler and smaller than the districts and authorities contemplated in acts for the creation of conservancy districts which have recently been passed in various States. These have looked more toward flood control and other things undertaken on a large scale. Of a similar order are acts relating to pollution-control districts and authorities. What is especially needed in addition to these is permissive legislation for the establishment of small districts or authorities, of any size and shape, for the regulation and control of little waters and of land use, so that any progressive area can organize for execution of a program, independently or in cooperation with the State and Federal Governments. There should be authority to establish, for any or several of a half dozen different objectives, local authorities over an area the size of a township or of a county, but irregular in shape and involving contiguous sections of several political jurisdictions. In some instances the existing political area might become the water-control and land-use district or authority, as in many cases of highway and sewer construction and administration, but it must be recognized that political jurisdictions rarely coincide with drainage areas, large or small.

One example of such permissive and directive legislation is offered by acts in several States, notably in Wisconsin and Minnesota, permitting the zoning of rural areas by counties. These acts are limited in purpose and scope, but they express the principle of permissive legislation directed toward the control of natural resources in relatively small areas. This legislation has been motivated primarily perhaps by the problem of financing educational, highway, and other social services in those marginal and submarginal sections of a county which are unable to maintain these for themselves; but it also gives opportunity for expression of a more rational policy of land use. Under conditions a county may zone its area, restricting the use to which sections having certain characteristics may be put. This permissive zoning, together with modification of the tax system in a manner to influence individual action in the direction desired, tends to cause a reallocation of lands inferior for tilled crops to timber and grasses, and a concentration of population in the more productive sections of a county. From the social point of view, as well as from the point of view of individuals struggling hopelessly to win a livelihood from infertile or eroded soils, a national program of reselection and wiser use of land is of major importance. Such a program, involving of course resettlement, is basic to rural rehabilitation. It is basic to most specific programs of betterment, such as provision generally throughout rural districts of adequate educational facilities, or good roads or electricity.

Another illustration, in the right direction and especially pertinent to our discussion, is the Wisconsin Act of 1935 "relating to relief of low-water conditions of navigable rivers and lakes."[14] This act permits surplus waters, under authority of the public service commission, to be diverted and stored for beneficial use. Independent of this legislation—

> during the last year or so the Wisconsin Emergency Relief Administration has constructed a great many dams, principally in drainage districts in north-central Wisconsin, to restore ground-water levels within these drainage districts. In some locations the restoration of ground-water levels was primarily to restore the water table for agricultural purposes which had been excessively lowered by the drainage ditches and drought periods. In other locations the dams were for the purpose of reflooding marsh areas where drainage had been found unprofitable. Altogether, several hundred of these dams have been constructed or are in prospect.[15]

In other States a water-conservation movement is gaining headway. For instance, North Dakota also has an extensive program of water conservation by damming both "dry streams"—coulees that carry water only during the season of melting snows and rains—and "wet streams"—those that do not carry water during the dry season, but do retain some in holes.

> A large number of these created bodies of water are large and deep enough to warrant the planting of fish, thereby creating a recreational center. However, this is not the only purpose of this work; our program is to build a series of dams in all the rivers and streams of the State to conserve the run-off water which otherwise has been carried down to the Gulf of Mexico.[16]

South Dakota's experience has led that State to favor a program of numerous small works. Oregon is transplanting

[14] Chapter 287, Laws of 1935.

[15] Letter from William M. Dinneen, Secretary, Public Service Commission, Oct. 11, 1935.

[16] Letter from A. J. Peterson, Commissioner, Game and Fish Department, Oct. 23, 1935.

beaver from places where they do damage to the upper reaches of small streams, where their dams will aid in a conservation program. Iowa is constructing a number of artificial lakes for recreational purposes. New Jersey has constructed since 1933 some 1,200 dams and snags in the open streams and these have doubled the fish capacity of the streams affected.

The relations of the Federal Government to the problem of control of small headwater streams and other small waters has already been indicated. The principal responsibility of the Federal Government involving direct action, frequently in cooperation with the States, has thus far lain in the realm of big-water problems—navigation, flood control, irrigation, reclamation, forest reserves, national parks, and so on. It now appears necessary that the Federal Government give not less attention to the problem of little waters. There are three principal ways in which it can and should bring its weight to bear in promoting conservation of heretofore wasted little waters and elimination of erosion: (a) continuation and extension of its research and educational work, including demonstrations, through such agencies as Soil Conservation Service, the Bureau of Agricultural Engineering, the Forest Service, the Geological Survey, the Biological Survey, experiment stations, county agents, and so on, coordinating these into a more effective group for planning and directing definite local programs; (b) establishing a permanent system of contributions to local projects, in cooperation with the States—funds, scientific, engineering, supervisory and other technical ability, and worker groups of C. C. C. type; and (c) by permissive and directive legislation which would facilitate the organization of small community districts or authorities whose physical characteristics indicate the necessity of an interstate conservation area.

As was said in the section on basic principles, physical factors have no regard for political boundaries. Problem areas do not coincide with political areas. The problems of such an area must be solved as a whole. Individual actions may be taken within an area, but to be economical and effective, they must be in accordance with a plan for the entire area. Therefore with respect to practically every particular problem, several levels of government will be concerned. If we desire to conserve and wisely use our resources, government on every level must stand ready to cooperate by doing its part.

Postscript:

MAN AND LAND

A VALLEY OF TOMORROW TELLS A STORY

He who knows what sweets and virtues are in the ground, the waters, the plants, the heavens, and how to come at these enchantments, is the rich and royal man.

—RALPH WALDO EMERSON.

AS YOU spin into the Valley on a pleasant summer day, it is ready with a smile and with a story. Fortunately the outlook at every point along the way is so restful that one slows his pace for the enjoyment of it, for he who rides slowly can read a part of the Valley's story in hills and woods, brooks and ponds, and cultivated acres.

The Valley is not of the rugged picturesque type; not mountainous but with low rolling hills, a few of them fairly steep, and a generous proportion of nearly level land. No line of superior hills stands out so that the traveler's eye can trace the watershed. Yet here is a definite drainage area, some 20 miles in length and varying from 2 to 10 miles in width; and it has many clear brooks and small streams which wind their way along the Valley to form what is locally called a river, although this river is not important enough to have a place on any general map. It is one of the least of a series of streams that contribute to the making of a great river.

Before the first settlers came it was almost completely wooded. Lying near the border line between the zones of conifers and hardwood, it had a mixed growth; a little pine and hemlock, but chiefly oak and maple, with scatterings of elm, walnut, birch and hickory, and a bit of tamarack in the low wet spots. Here and there were stretches where the forests were thin, even though the soil was fertile—"openings" the first settlers called them. Generally the glacial clay, gravel and sand subsoils were covered with a layer of rich top-soil and a humus created by the rotting of leaves and branches and fallen trees through many centuries. In the openings and among the bottom lands were areas of rich natural grasses. Game was then abundant; deer, foxes, rabbits and some bears, muskrats, and beaver. The creeks ran full and clear, with many a backwater pool, and were filled with fish. When the surveyors of the Government came to lay out the sections and the quarter-sections they confirmed the reports of earlier explorers and settlers that it was a rich Valley, and soon the word spread to the East. Then came the permanent settlers to clear the land and establish their homes.

The mode of livelihood which was established by the settlers who soon took up all the land in the Valley was natural and inevitable from the point of view of their generation. The old world as well as the new world needed food and raw materials; and therefore these were crops which provided the ready cash with which the farmer could buy implements and other necessities, hire labor, and pay taxes. The demand for cereals, meat and wool, and for eggs, butter and cheese, created an incentive to clear the land as rapidly as possible; and the demand for lumber with which to build villages, and to construct agricultural implements, wagons, buckboards, and other necessities of a newly settled country, created a more direct incentive. For all of these crops there were competing dealers in the village down at the foot of the Valley—there was not then a settlement at the Center—many of them proprietors of general stores and agents of implement manufacturers, ready to barter with the farmers for every kind of product and to pay hard cash for any balance due. The Valley became a prosperous middle-western farming community, based on mixed agriculture, the backbone of the country half to a quarter century ago. In the presence of the abundance of resources on every hand no suspicion could enter these settlers' minds that this might not be a permanent country.

But eventually came a change; a decline of farming as a mode of livelihood and of rural life as a mode of living; a period of gradually increasing distress, accelerated by the Great War which stimulated activity and hastened collapse.

War prices led the farmers of the Valley to put every ounce of pressure on the land. During the war they were led to believe that it would be unpatriotic to do otherwise. Every possible cleared acre was plowed under. Plowing was extended farther up the hillsides, and grazing was intensified on the remaining sod lands and openings. Many young farmers purchased land from retired owners at high prices, and others bought and sold. Everyone went heavily into debt, for credit was easy and many of the country bankers thought the high prices would last forever.

That was a disastrous prophesy. All of what happened is not even yet understood. Forces in the Nation outside the Valley, for which its people could not be held responsible, combined with forces within the Valley for which they could be held responsible, caused a huge decline in agricultural income, and distress appeared everywhere among its people.

As for the destructive forces within the Valley for which its people were responsible, they came to understand them. They came to understand, among other things, that they had been robbers of the land by their farm practices—had been robbing themselves, their children, and their children's children.

They realized that one reason they were not receiving the accustomed income from their efforts was that the yield per acre had been declining. They had thought it was because of declining fertility caused by the plant food taken up and carried away by the crops, and that there was nothing to do for that except ever more fertilization and more expense. But they learned that it was something worse than that; they had been robbing the fields of their fertile topsoils, had been encouraging the rain, snow, and wind to carry them away. They had cut over the forests recklessly—in some instances had burned the timber the more easily to get at the soil underneath. They had crowded so much stock on the pasture land that the very roots were being eaten out and the growth destroyed. The washing of the fields had in some places gouged gullies that made it impossible to work the land. Springs and creeks were drying up and in some seasons on some farms there was not water enough for the stock. Some farms were being abandoned.

Finally the people in the Valley joined together in a "recovery campaign." It is interesting how such things start—always because of one or two people with vision, energy, and high regard for the community in which they live.

The owner of the general store and one of the leading farmers read some books on conservation suggested by the county agent and realized what could be done to restore and improve the Valley. For a time they could hardly talk about anything but erosion and water table and contour plowing and vegetative cover and reservoirs and supplementary irrigation; and electricity for the farmers, and running water and bathrooms. They talked with the county agent, and went with him over to the agricultural college, had conferences, and brought back bulletins on erosion control, agricultural engineering, and similar subjects. Before it was realized that this was more than a passing fad, they had the farmers and everybody aroused and organized for erosion control, and soil and water conservation. The specialists from the nearby experiment station and from the Government helped to form and to carry out their program.

Now as you go up to Valley Center, go slowly and notice everything. When you get to the top of this grade stop and get out of your car; take in the picture of prosperity on every side. You will see much forest, some of it still young growth, and many ponds; but also here and there spots of rich pasture land and fine stock; and on every hand you will see some fine farm land, splendid crops, and orchards heavy with fruit. Only the soils of suitable slope and fertility are cultivated; the next best are grazed; and most of the

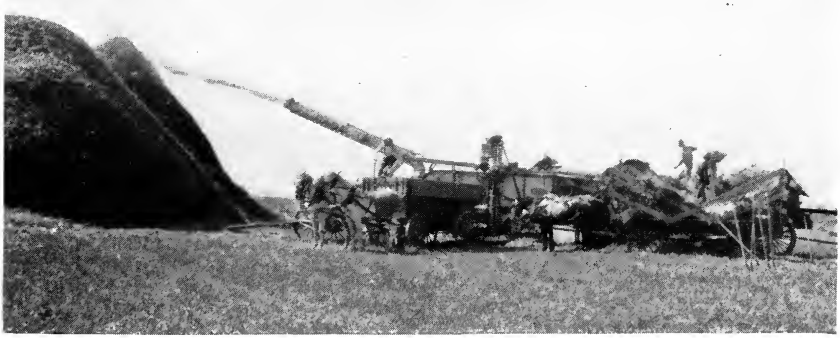
U. S. AGRICULTURAL EXTENSION SERVICE

Figure 49.—Comfort and contentment are the reward of working with Nature.

U. S. AGRICULTURAL EXTENSION SERVICE

Figure 50.—Grass conserves soil and water and yields cash income.

Figure 51.—A crop rotation plan conserves soil and moisture, diversifies income, and spreads risk.



U. S. BUREAU OF PLANT INDUSTRY

U. S. FOREST SERVICE

Figure 52.—Woods, ponds, and a cool swim on a hot day.

ASSOCIATED PRESS—KEYSTONE

Figure 53.—Swamps, marshes, and the call of wild fowl.

Figure 54.—Lively streams, shaded pools, and the lure of the crafty trout.

U. S. NATIONAL PARK SERVICE

rest is planted with trees and various kinds of bushes. Many springs have reappeared and brooks have a better flow during the summer months.

Take the time to walk over one of the farms. Not an owner will object; he will be proud to have you see his farm. You will see contour plowing. Here and there you will see terracing and strip-planting—a lot of small fruit and berries are grown that way now—some of it for game birds as well as humans, in addition to the regular orchards. Check dams are causing old gullies to fill rapidly and frequently you will find plowing and planting right over the site of a former gully; in other places they have been planted to trees. The farmers whose lands have been restored to forest use have moved to better lands in the Valley bottom, and are becoming prosperous again.

On some farms, those having favorable sites, you will find small reservoirs. Most of these reservoirs are not permanent, merely hold back the water until it soaks in, but many are permanent and furnish water for irrigating the gardens and other high-value crops when a season is dry or the rain does not fall at the right time; and for the stock, and for use in barns and houses. Drinking water, however, is generally pumped from the ground. Some of the farms near and below Valley Center, which do not have proper sites for individual reservoirs, are connected with the big reservoir at the Center. Of course it will not seem so big if you have seen the power dams down on the lower river, but it is the largest in the Valley, and they call it the "big reservoir." It has a small power plant.

Of course these permanent reservoirs are much lower in the late summer, after they have been drawn on for irrigation, than after the spring rains, but somehow they never go dry. These woods and pasture lands seem to feed them all through the summer; there are as many springs as there used to be before the Valley was settled, and the wells keep full.

The woods and meadows do not do it all. For instance, you may have noticed that the roads are well graded and drained; but also that in some places water from yesterday's rain is still standing in the ditches. An arrangement of baffles about 15 or 18 inches high, or drop inlets to culverts, keeps back some of the flow and does not let all of it get into the river and down stream. They let the water soak in. The experts told the people not to rush every bit of water straight to the river; to keep back as much as they could and let it infiltrate. It is reported that the people in the city where the little river joins the river below notice a difference in the flow there; their floods are not so high in the spring, and the river does not get so low in the summer, and is cleaner. It is also reported that the people in the city are enjoying fishing and boating again; the people of the Valley are certainly getting good fishing.

After you have taken a tramp over one of these farms, go to the buildings, visit the dairy. You will find plenty of clean, cold running water; and if you visit one of the houses you will find running water in the kitchen and a complete bathroom. Stop at one of the "Tourists Accommodated" places up the road and see something unusual—rooms with shower baths.

Since they have had electricity in the Valley it is like living in town. They had to wait a long time for it, but finally it came. You have noticed the distribution lines as you came up the road. In the house, of course, comfortable lights in the evening, a refrigerator, washing machine, ironing machine, and other devices; and every house has its radio. A few of the farmers have electric stoves; they say that farther south, a much larger number have electric stoves. As for the men, there are electric lights in the barns and sheds, and electric pumping of water from the reservoir or creek for the stables, the dairy, and the watering trough; and most of the farms use portable power machines for a variety of things—sawing wood, cutting ensilage, grinding feed.

The power comes two ways: During a considerable part of the year the farmers get it from the little station at the reservoir at Valley Center, but in the summer when the water is more precious for irrigation, they get it from a hook-up with the company station on the river below. The company did not take to that arrangement at first, but since all the lines have been hooked together in this part of the country, and since the Valley has become electricity-minded, it finds that it is good business. Of course, the most important thing was the reduction in rates. It seems that every drop in rates turned out to be a good thing for all concerned—for the power company and dealers in electrical equipment as well as the consumers.

When you reach the Center you will find an interesting and unusual community. It is a small, unincorporated village, made up of half a dozen little factories, two or three retail stores, and 25 or 30 houses. Most visitors are surprised that such a small community has so many little factories. But their establishment seemed to be a natural development after plenty of cheap power was available and the farmers were raising a greater variety of crops. The farmers were largely responsible for these factories because in carrying out their farm improvement program they discovered how much could be accomplished by working together. The small factories now give an outlet for some farm products, regular work for some of the people, and part-time work for a larger number. Of course the little lumber mill, the creamery, and the blacksmith shop, more like a little machine shop now, are enterprises which had disappeared and have returned. Unlike the old-fashioned grist-mill which made ordinary white flour, the new mill makes a very special whole-wheat flour and does not compete with the big mills in the cities. It has its own brand name, and has a market for all it can produce. This is also the case with the fruit and jam factory. A visit to this plant will convince you that the canned fruit, jam, spiced pickles, and apple butter are as near home-made as can be found. Likewise, the little factory that makes sausages and pressed meats has its own brand names and distributes its products in the nearby cities, and also sells by mail order. The market readily absorbs the entire output because of the high standards of quality maintained by the workers. Every bit of the raw material is raised in the Valley, and is of the best.

By the way, you should stop at the Valley Center Inn overnight. It is not very pretentious, but it is neat and clean; and as for the cooking—you will find that out for yourself. Stop there—good fishing is waiting, and before leaving watch the boys in the swimming pool. And look over the picnic grounds; several families will probably be having their supper. Enjoy the evening, and after a good night's sleep, you will be planning to come again.

It is impossible to tell the whole story; a first visit can give one only a cue as to what to look for—why it is a prosperous and happy Valley, and how mutual efforts have brought their rewards.

UNITED STATES GOVERNMENT PRINTING OFFICE : WASHINGTON : 1936